RUN10: RHIC Orbit, Tune, Coupling, and Chromaticity Feedback

I tune/coupling feedback (fully operational)

II ramp orbit feedback (new 2010)

III simultaneous orbit, tune, coupling feedback

IV chromaticity feedback (new 2010)

V simultaneous orbit, tune, coupling, and chromaticity feedback

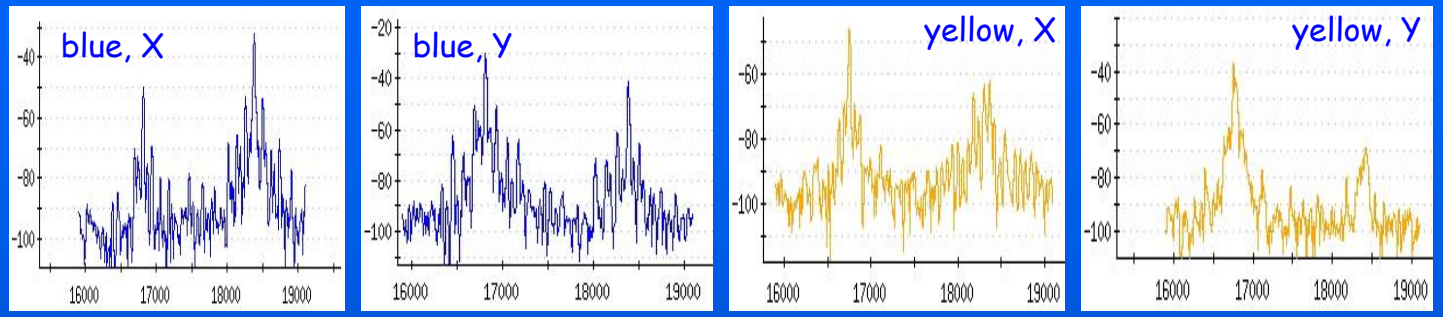
VI simultaneous tune, coupling, and chromaticity feedback (revisited)

VII plans for run-11 : the above plus store orbit feedback

VIII credits

I RHIC tune/coupling feedback (fully operational)

run-10



DSA spectra (02/04/10) at injection energy – "anomolous BTF?"

implemented digital filters in all planes

phase-jump-compensator implemented 07/04/09 used continuously (Marusic, Mernick)

developed extensive checklists and further simplified procedures for operations (Wilinski)

PLL coefficients set for high-precision (as opposed to fast tracking)
upgraded to support measurements with 1/3 < Q < 2/3

used to diagnose problem with new magnet transfer functions
tune and coupling feedback on all ramps until declaration of physics
tunes and coupling measured for each and every ramp (operations)

Improvements for operational baseband tune (BBQ) and coupling measurements and feedback at RHIC, M. Wilinski et al, Beam Instr. Workshop (2010)

High precision tune and coupling feedback and beam transfer function measurements in RHIC, M. Minty et al, Intl. Part. Acc. Conf. (2010)

II RHIC orbit feedback (NEW 2010)

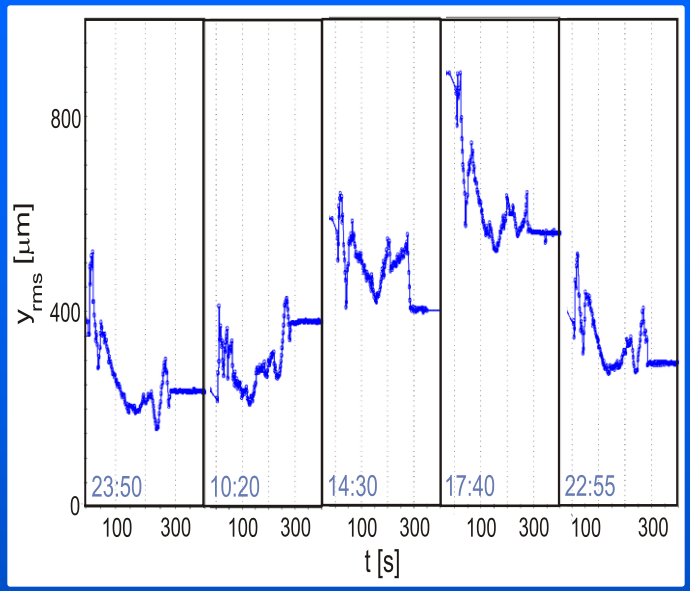
measurement

based on existing beam position monitors

using new and improved algorithm for measuring average orbit – R. Michnoff

using original survey (e.g. offset) data – T. Satogata

deterministic data delivery



feedback design

orbit correction algorithm ("singular valued decomposition") by V. Ptitsyn

extended to application at 1 Hz rate during energy ramp – G. Robert-Demolaize

implementation

reference orbits specified in terms of BPM data (no longer corrector strengths)

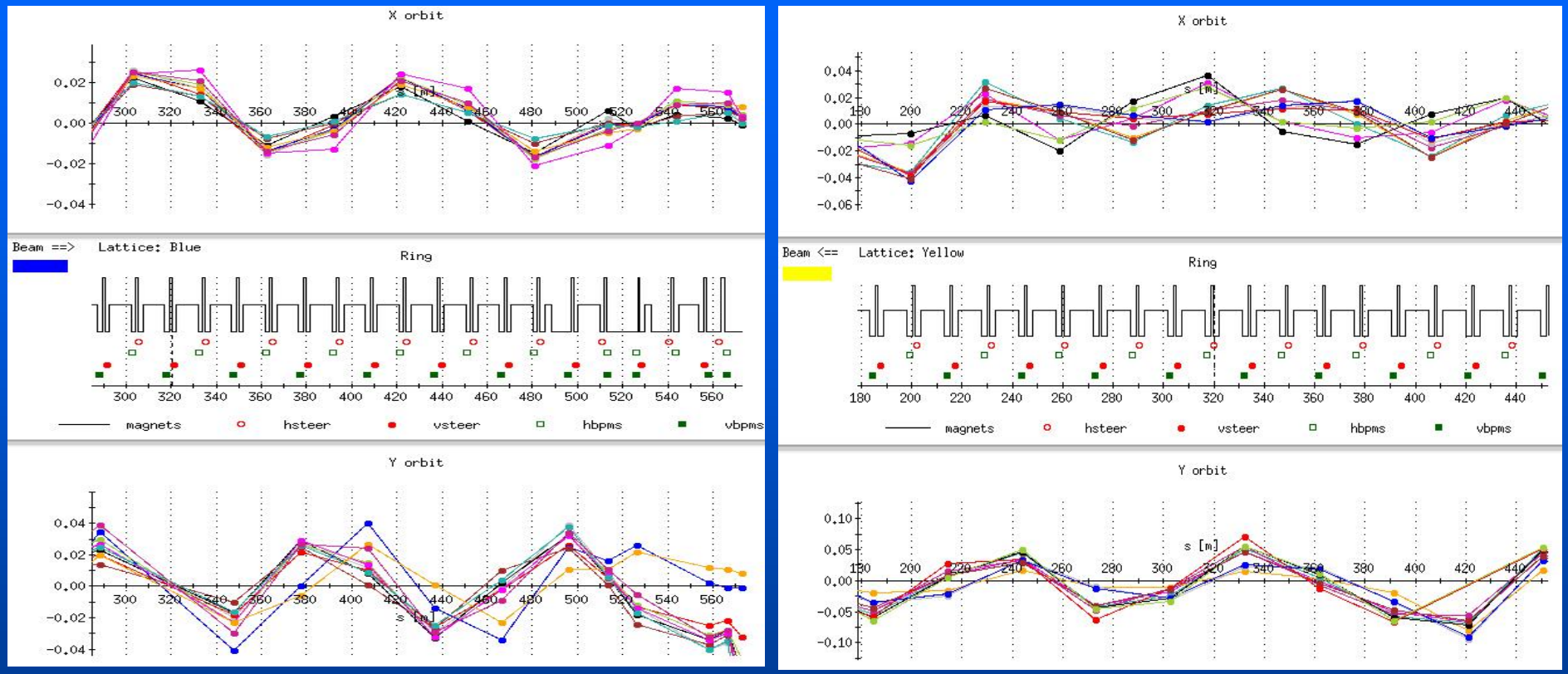
new ADO manager for gathering data, computing and distributing corrections

ramp-down, feed-forward , and replay of corrections

Slow orbit feedback at RHIC, V. Ptitsyn et al, Beam Instr. Workshop (2010)

RHIC orbit feedback development: BPM precision

Measurement-to-measurement (4 s intervals) fluctuations in the difference orbit:



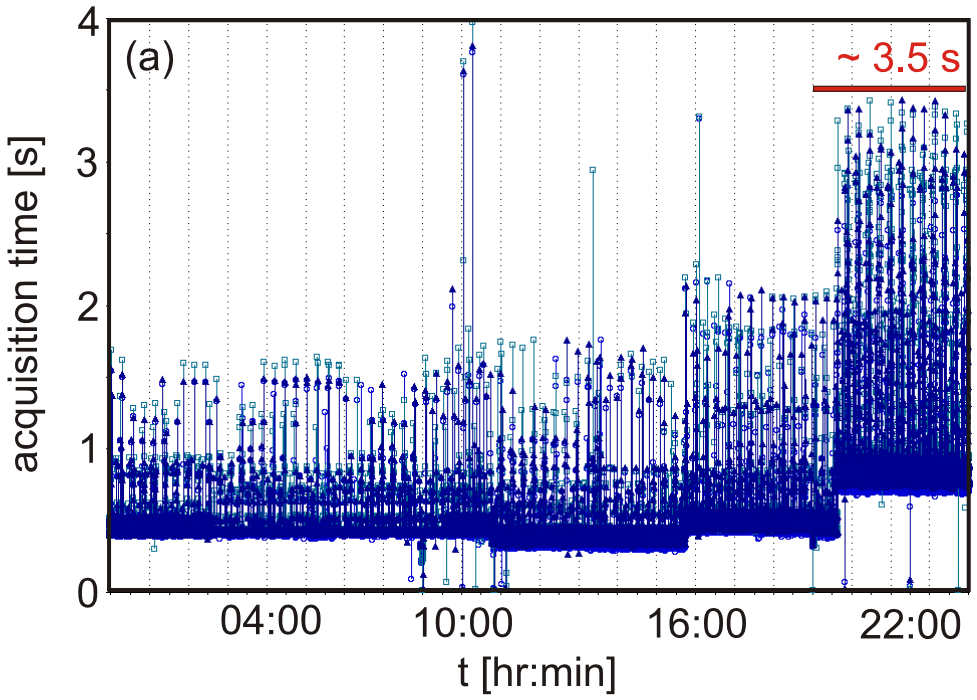
… evidencing precision measurement of orbits with BPM precision < 5 microns
(and evidence of externally driven coherent betatron oscillations)

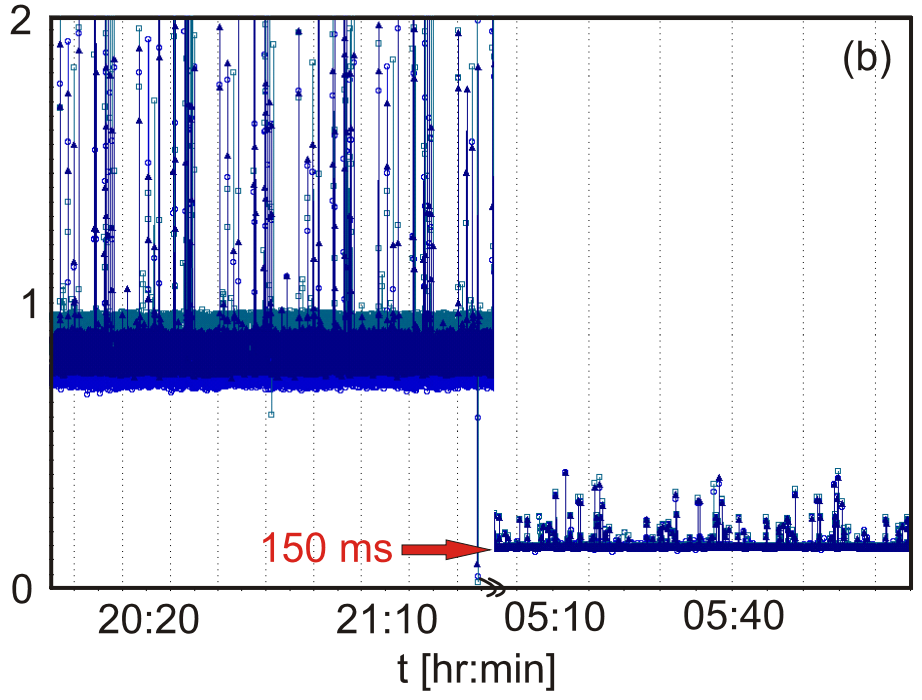
RHIC BPM average orbit calculations, R. Michnoff et al, Part. Acc. Conf. (2009)

RHIC orbit feedback development: BPM data delivery

pre-RUN10
- acquisition rate: nominally 0.5 Hz
- nondeterministic

RUN10
- acquisition rate: 1 Hz
- deterministic





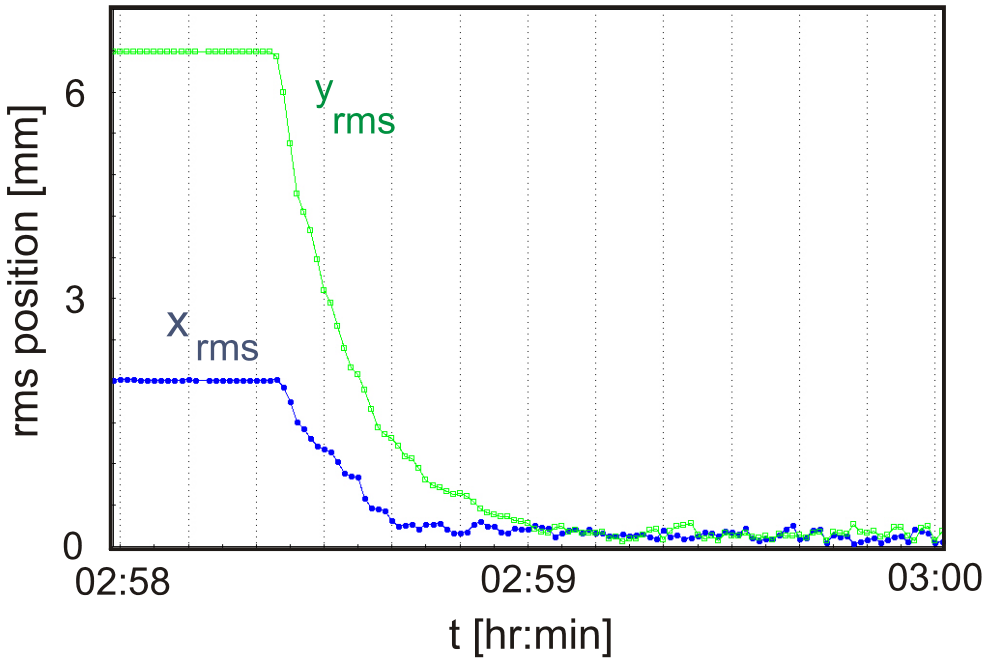
Global orbit feedback at RHIC, M. Minty et al, Intl. Part. Acc. Conf. (2010)

RHIC orbit feedback development: convergence tests

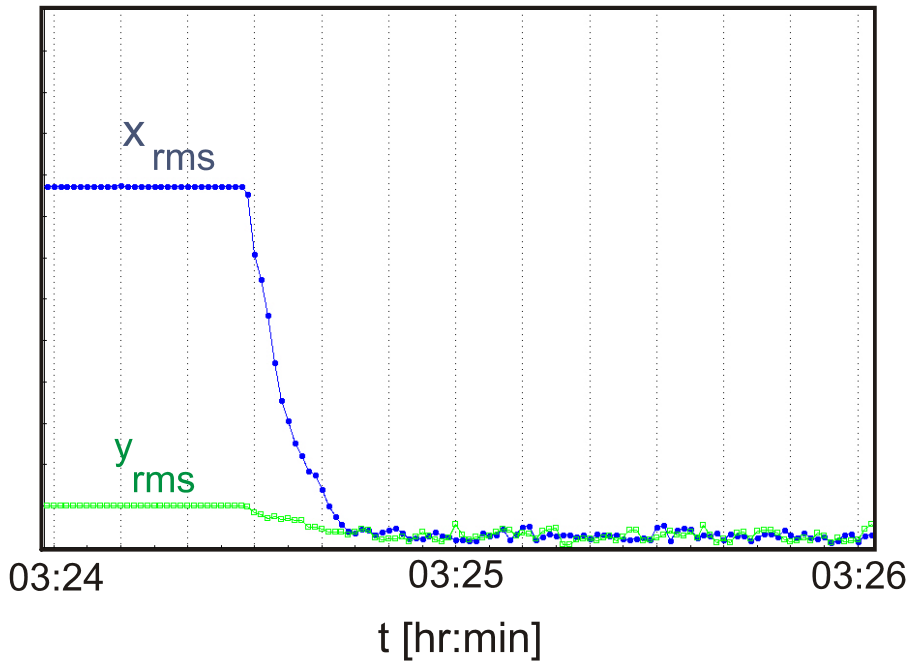
at injection energy: 1) "randomize" orbits
2) measure rms of BPM readings as fb is engaged

N_{BPM} ~ 150 per plane
N_{COR} ~120 per plane

blue ring



yellow ring



blue: no change in loss rate

yellow: accompanied by beam loss

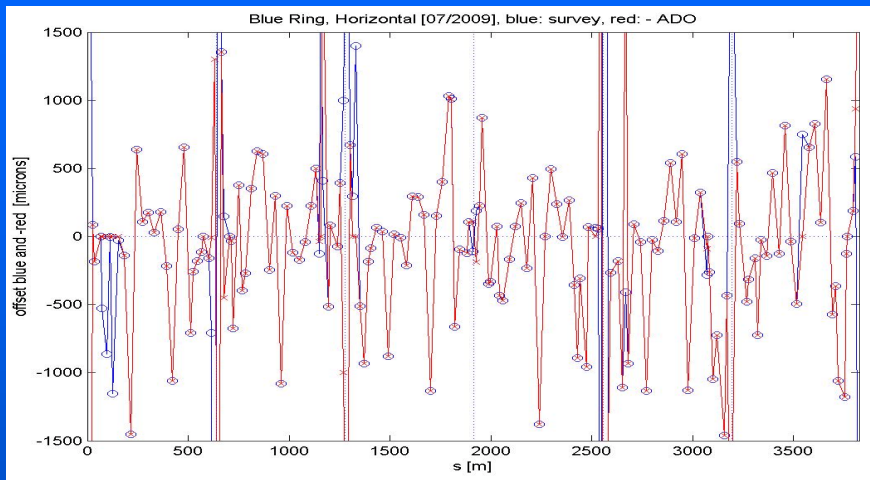
RHIC orbit feedback development: BPM offsets

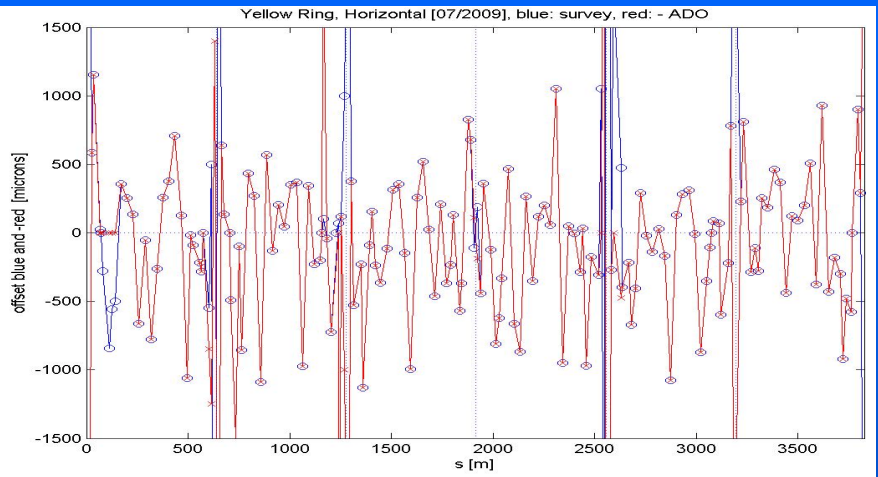
blue ring

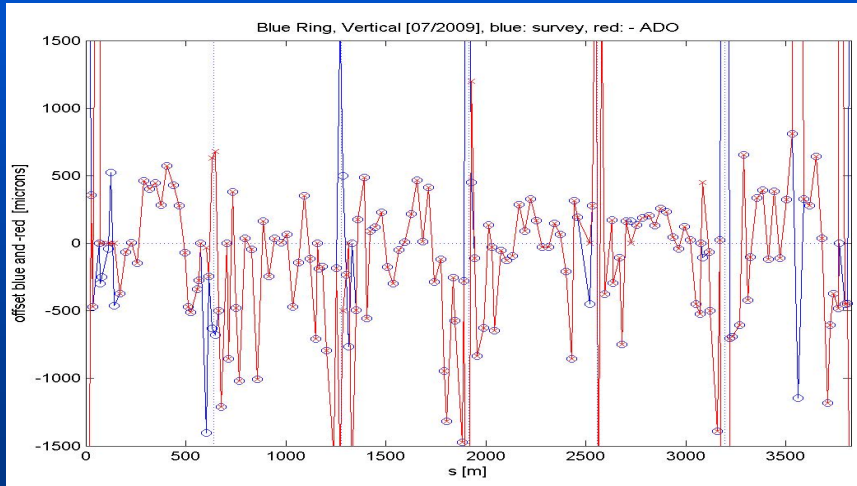
yellow ring

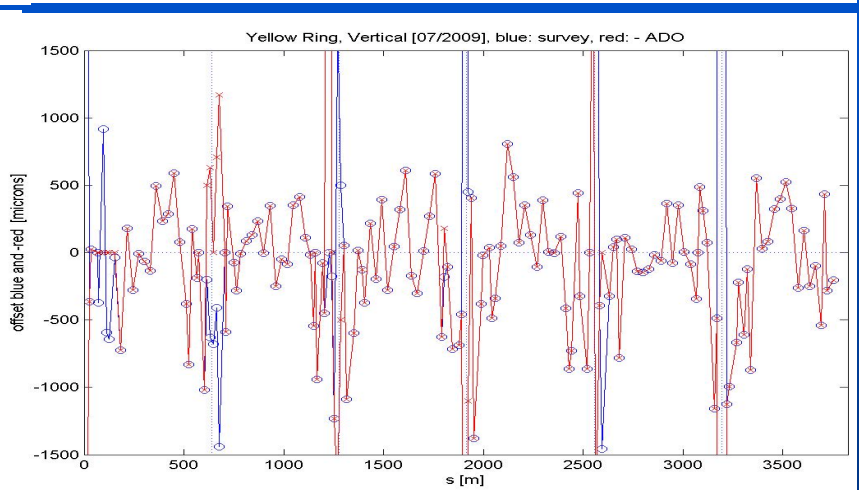
horizontal

vertical







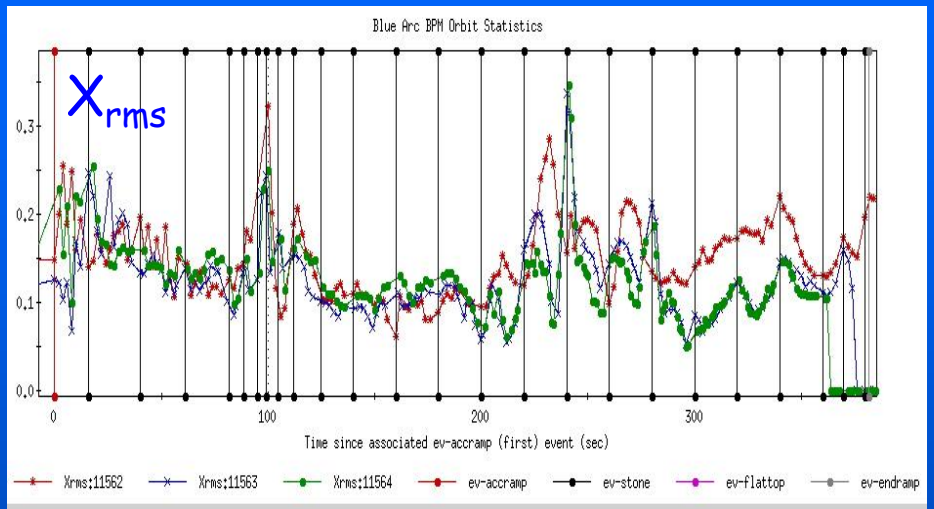


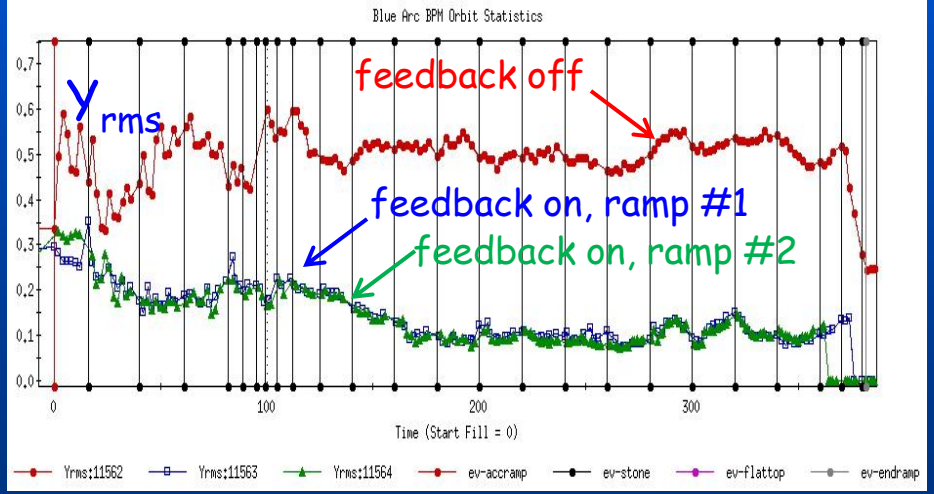
vertical offsets – all signs reversed on 01/07/10
horizontal offsets – 50% of signs reversed on 01/13/10

T.Satogata

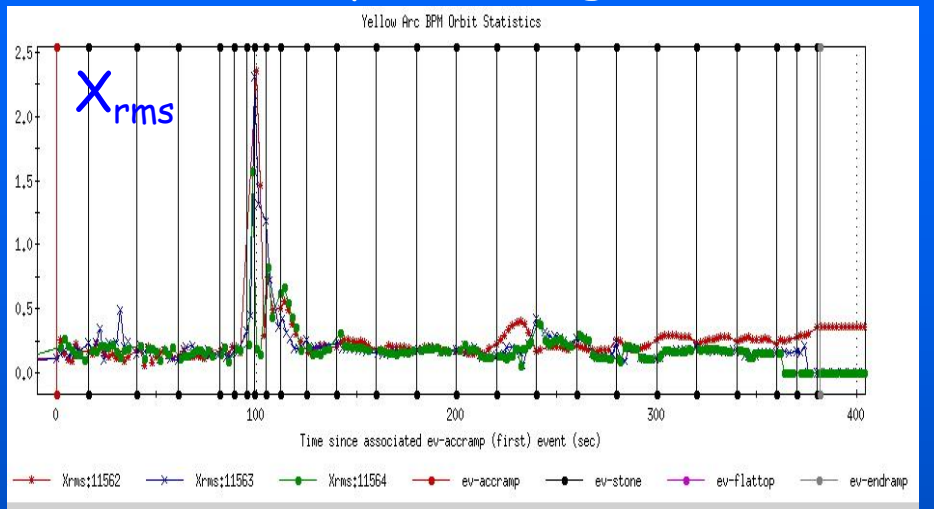
RHIC orbit feedback: proof of principle – APEX (01/27/10)

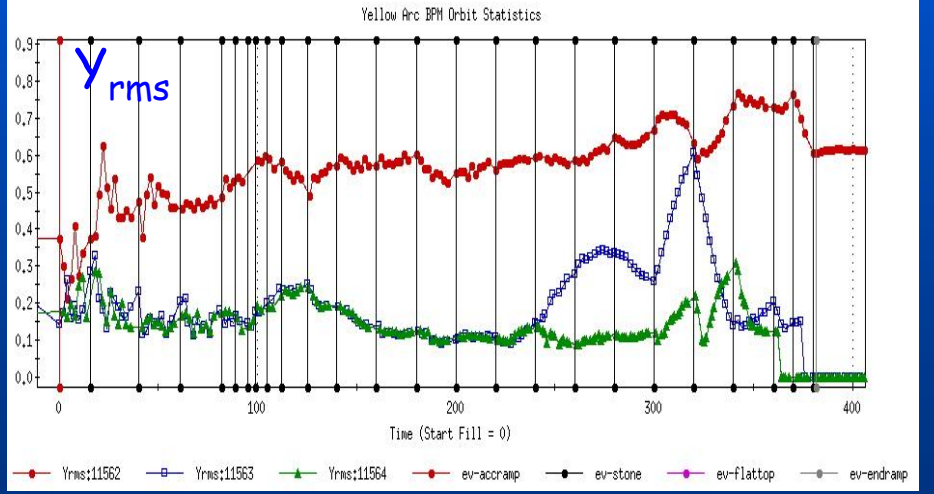
blue ring





yellow ring

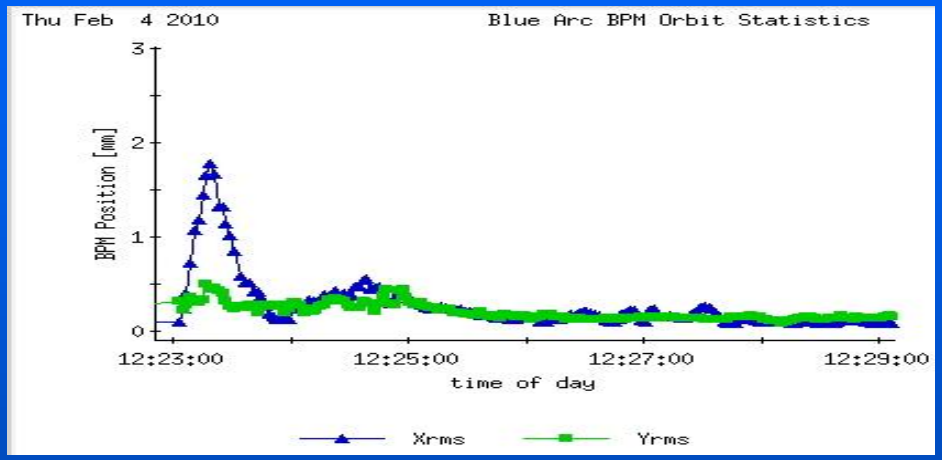




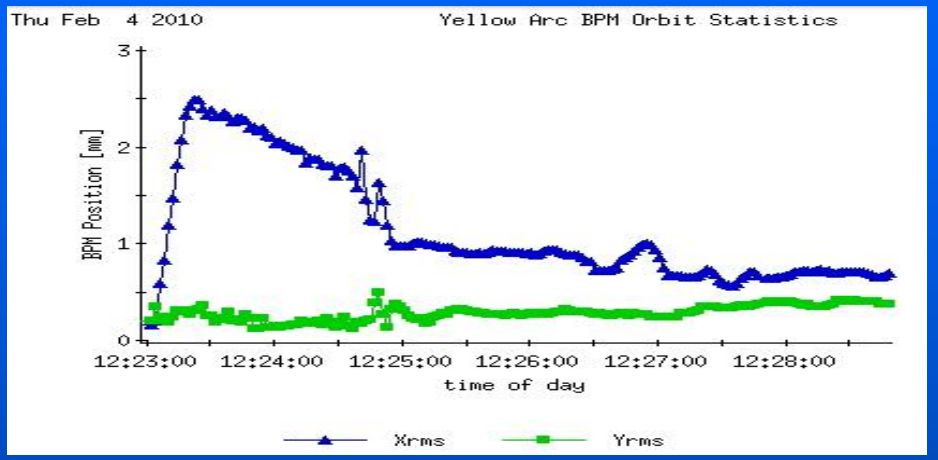
yellow: BPM database error found and bypassed, no more beam loss thereafter

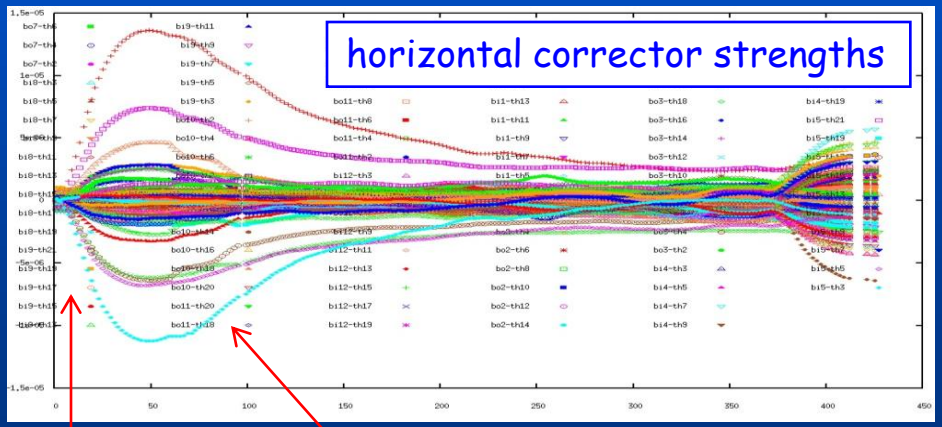
III RHIC simultaneous orbit, tune, coupling feedback: STAR solenoid reversal (02/04/10)

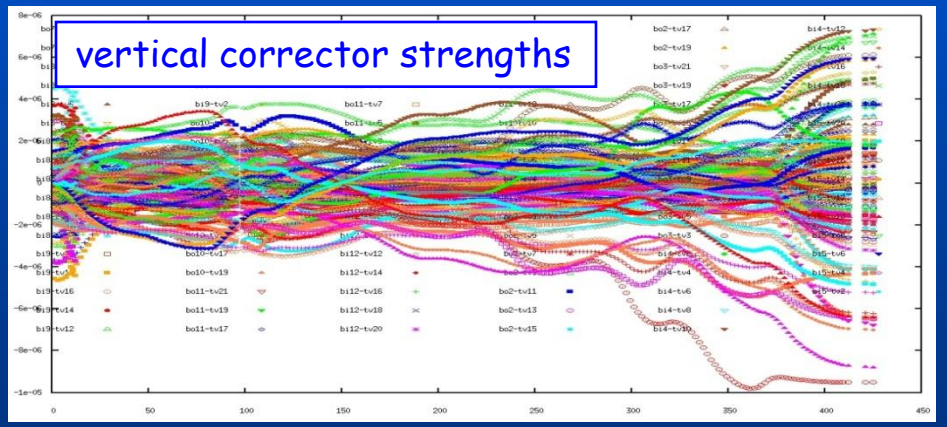
BLUE RING: orbit/tune/coupling feedback



YELLOW RING: tune/coupling feedback







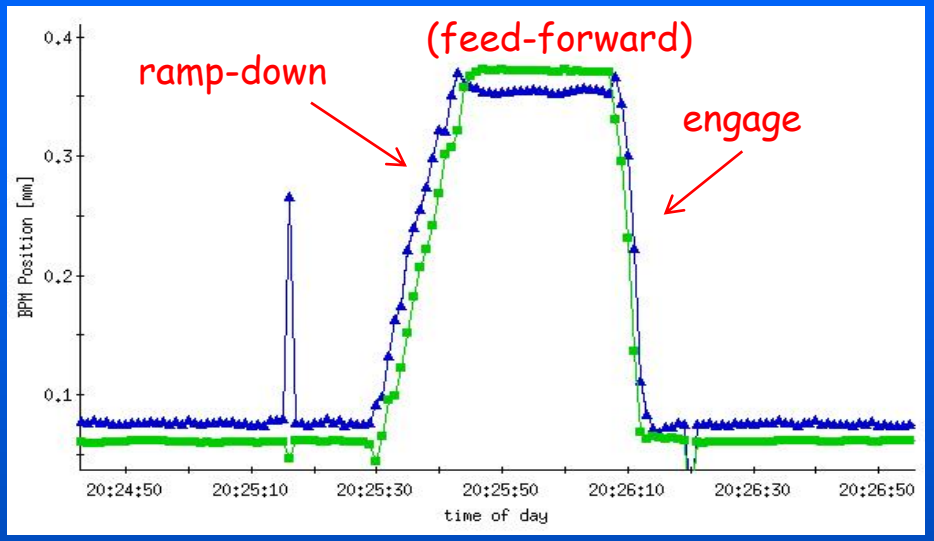
effect of solenoid reversal corrected at injection

feedback compensates orbit distortions

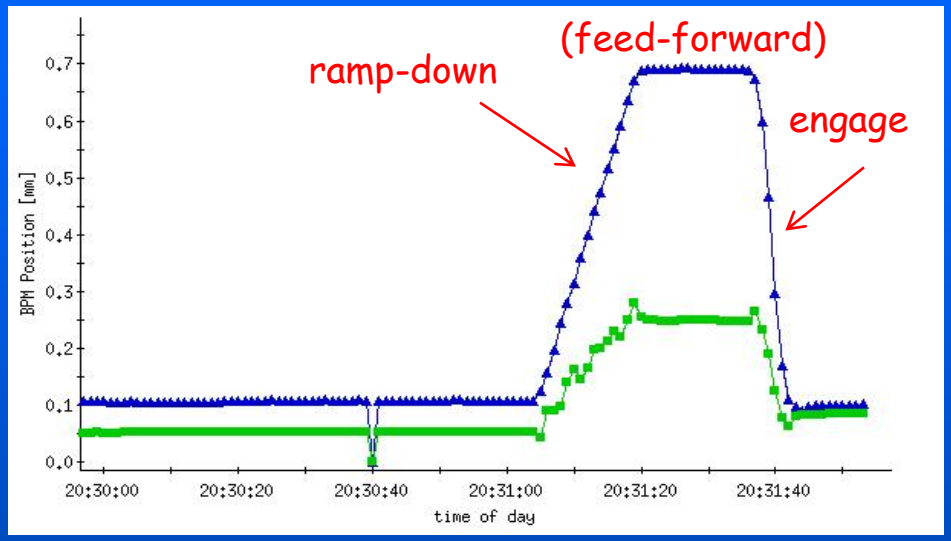
first ramp [11625] efficiencies: 95% / 98%

RHIC orbit feedback development: feed-forward and replay

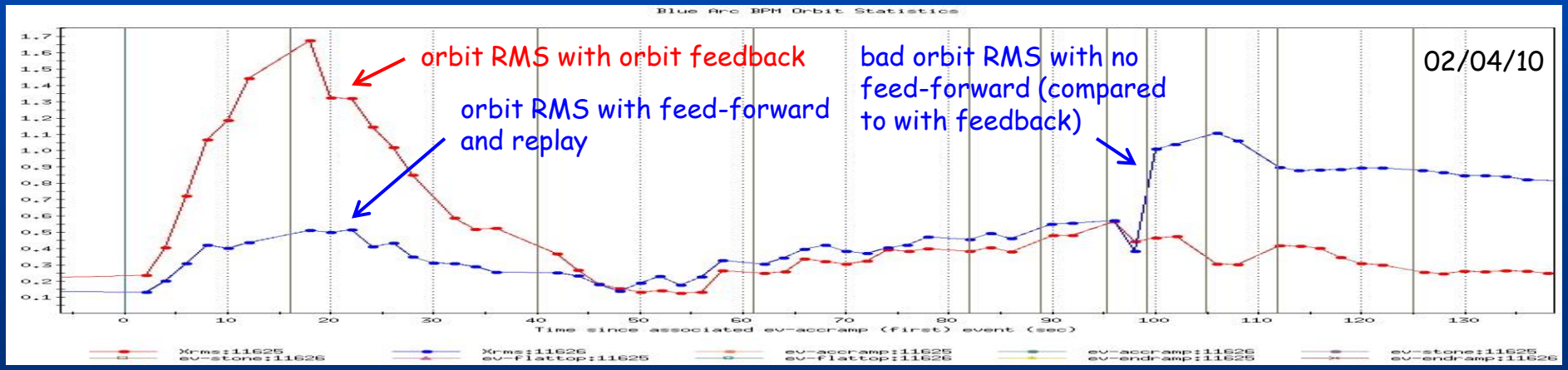
blue ring



yellow ring



partial feedforward (up through transition crossing, where closed-orbit distortions due to solenoid reversal were most severe)



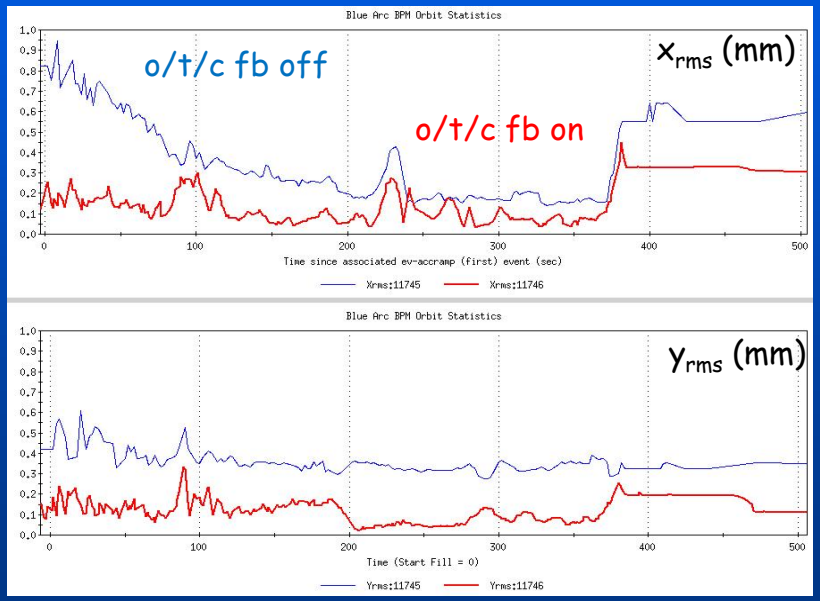
RHIC simultaneous orbit, tune, coupling feedback: PHENIX solenoid reversal (02/18/10)

BLUE and YELLOW rings : orbit, tune, and coupling feedback + feed-forward and replay

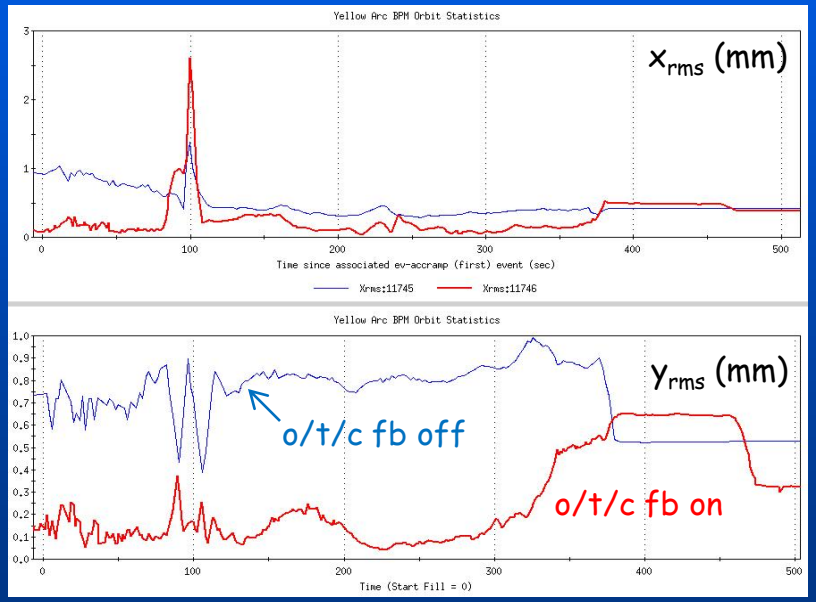
PHENIX solenoid reversal

first ramp: no feedback [11745] efficiencies : 63% / 74% (transition loss)
second ramp: o/t/c both rings [11746] efficiencies: 92% / 95%

blue ring



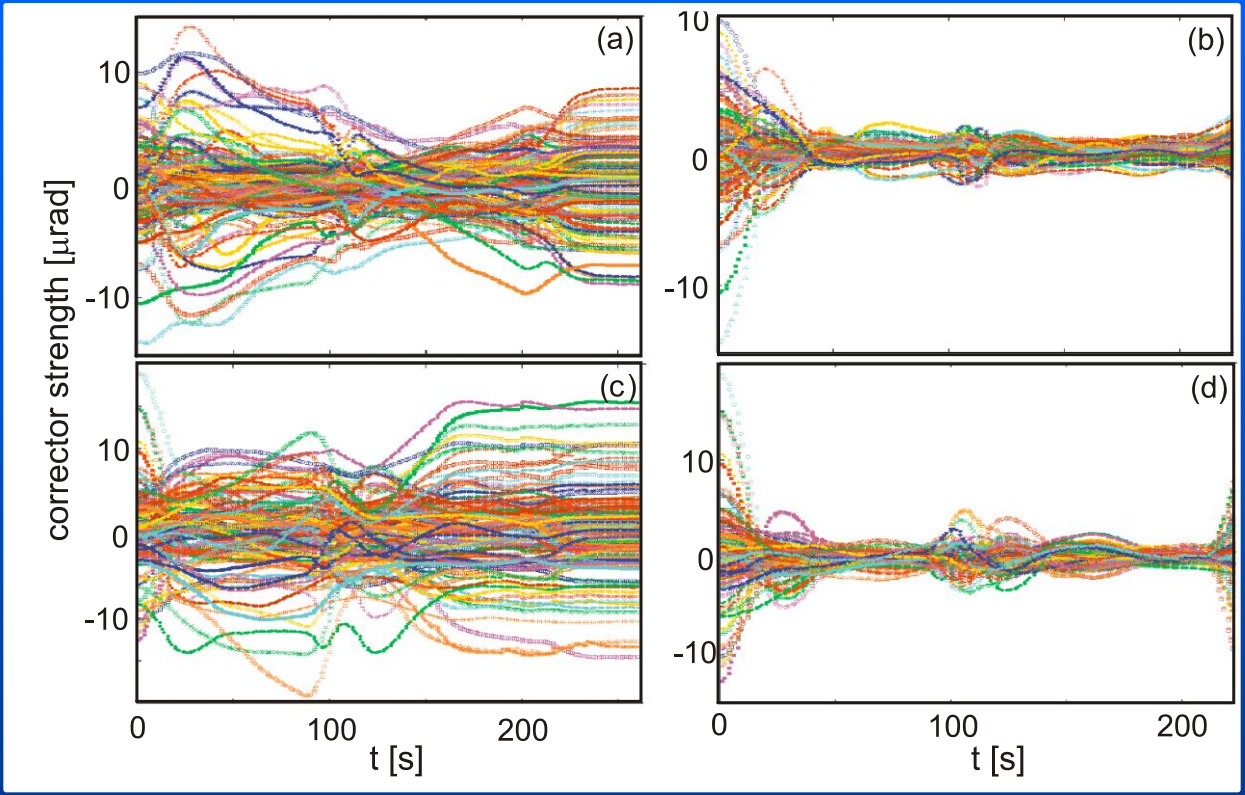
yellow ring



not "too" challenging, mostly examining BPMs, exercising feed-forward of corrections and developing diagnostics for ensuring good data integrity and assessing performance

RHIC simultaneous orbit, tune, coupling feedback: new optics - Au106, 62.4 GeV (03/18/10)

first ramp: second ramp:



first ramp: o/t/c both rings [11936] efficiencies: 97% / 97% (then FFW)
second ramp: o/t/c both rings [11937] efficiencies: 91% / 88%

⇒ convergence of correction algorithm after one application of feed-forward

IV RHIC chromaticity feedback (NEW 2010)

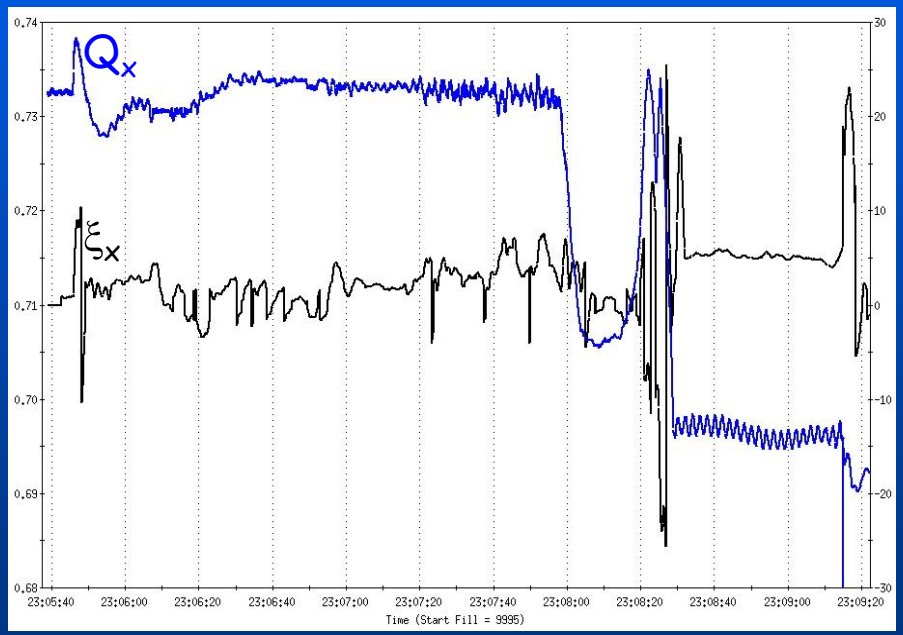
measurement

based on existing beam position monitors + rf frequency modulation
based on S. Tepikian's improved algorithm for measurement of chromaticity

feedback design and implementation

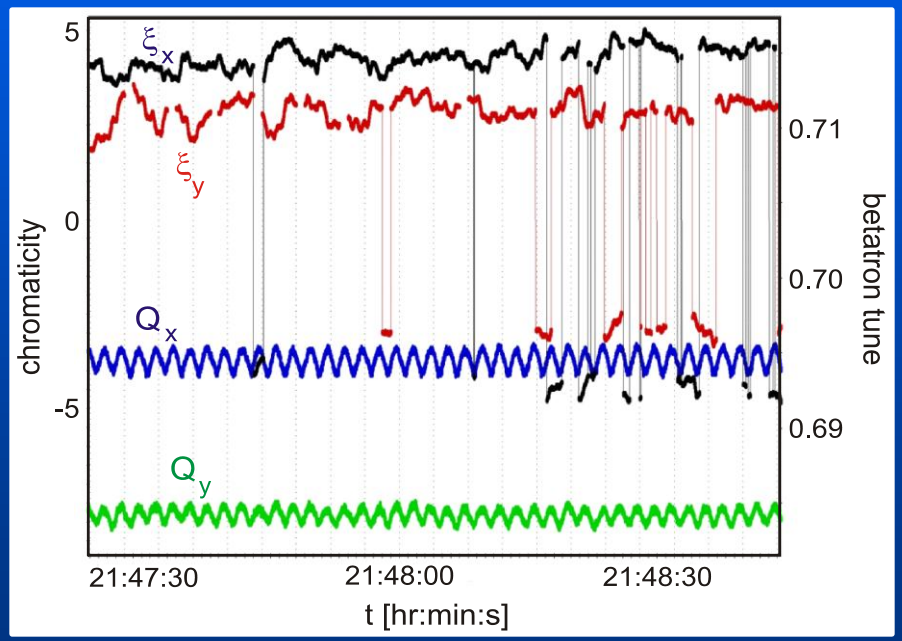
feedback algorithm, ramp-down and feed-forward of corrections

run08



issue with quality of tune data
(focus on "hybrid-tracker" development)

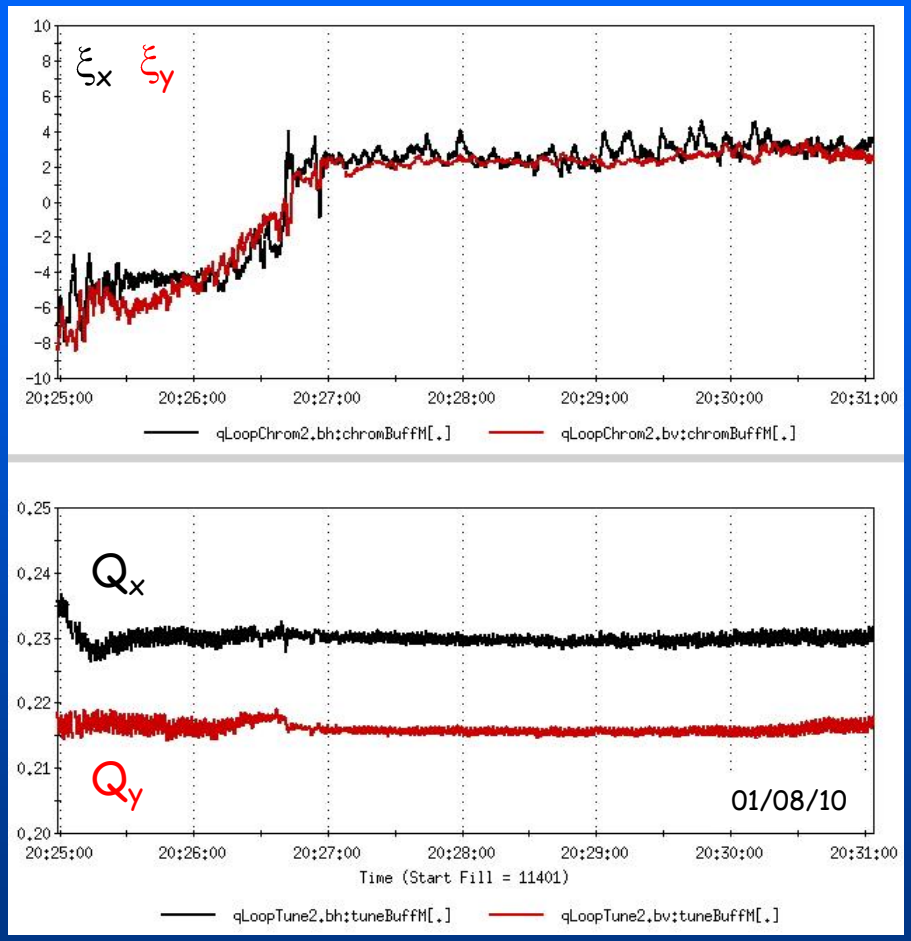
run09



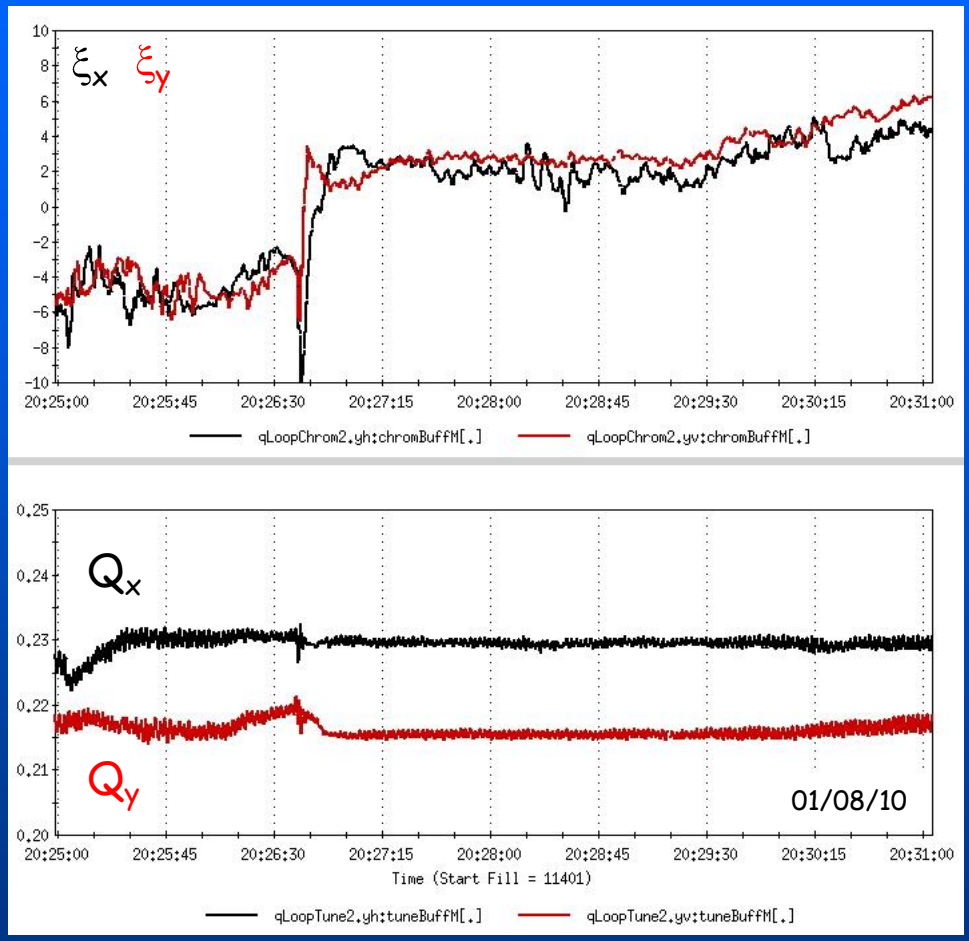
tune data improved
problem in algorithm (sign flips) revealed

RHIC chromaticity feedback development: data integrity

blue ring, ramp chromaticity measurement



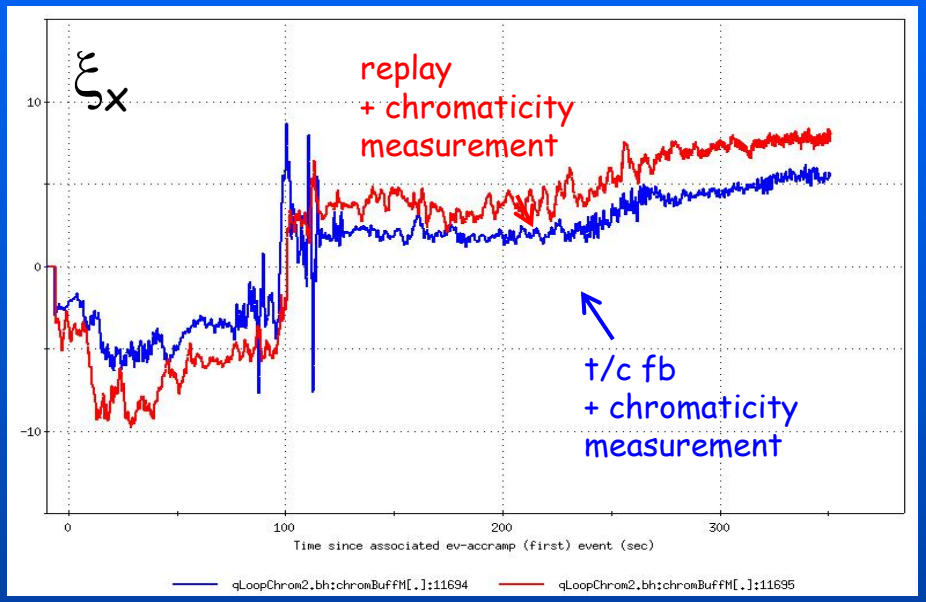
yellow ring, ramp chromaticity measurement

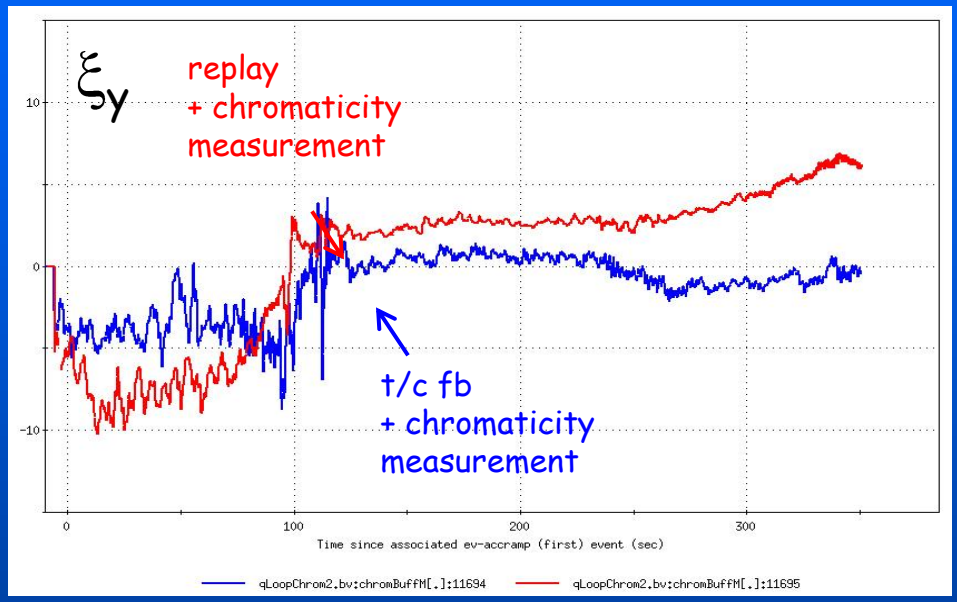


algorithm modifications and improvements
verified data integrity in the blue (12/23/09) and yellow (01/06/10) rings

RHIC chromaticity feedback development: handshake with tune and coupling feedback

02/12/10, APEX - ramp t/c+ chrom measurement (blue ring)





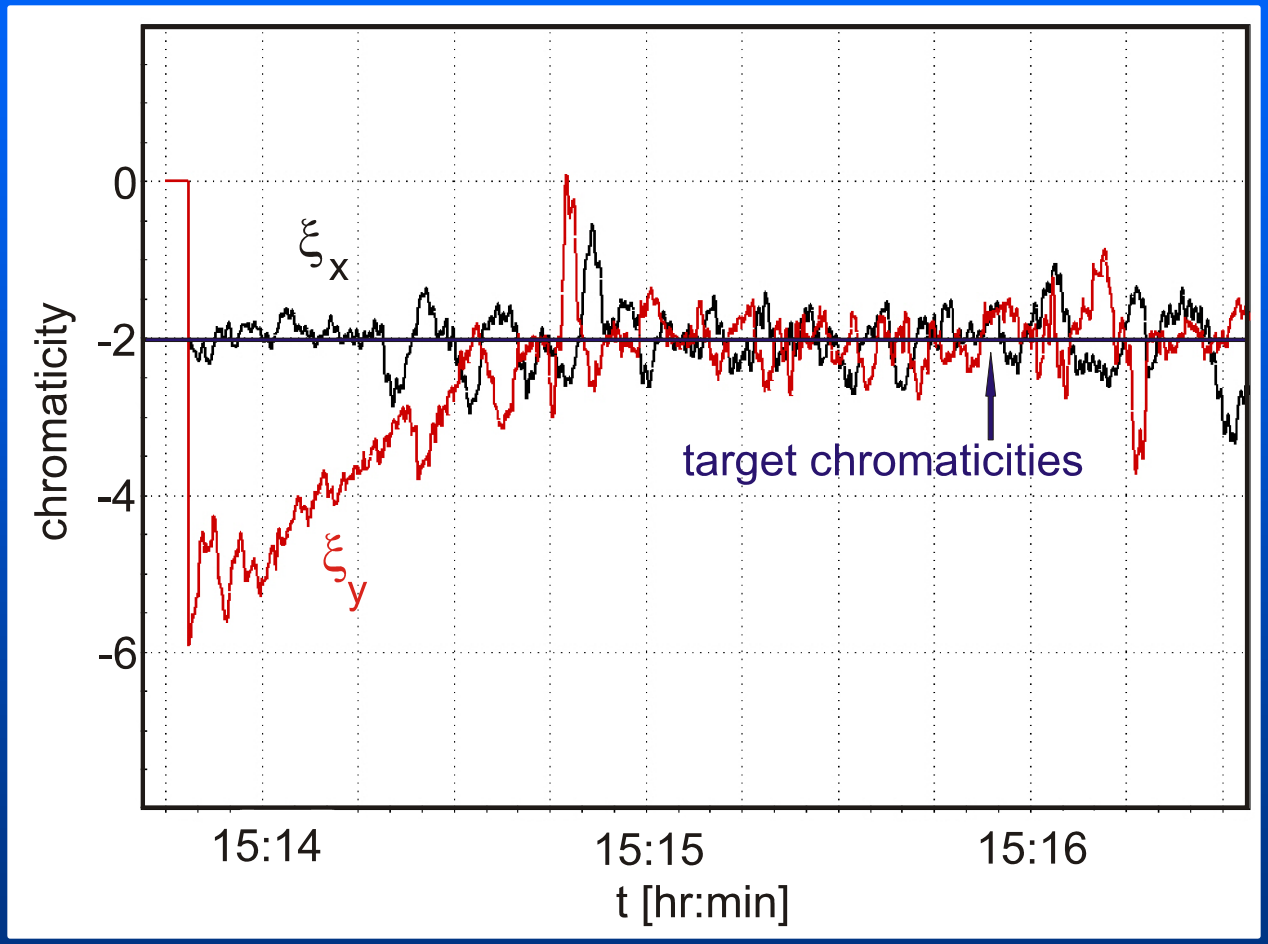
02/24/10, APEX - injection t/c + chrom measurement + chrom modulation
03/01/10 - injection t/c+ chrom measurement + chrom modulation

encountered difficulty with 120 Hz harmonics near betatron frequencies at injection energy
identified and corrected RTDL 23-bit limit (+ handshakes w/ drift compensation)
identified and corrected handshake with starts of rf frequency modulation and chromaticity measurement
improved algorithm for detection of radial modulation

RHIC simultaneous tune, coupling, and chromaticity feedback at injection energy

★ APEX 03/03/10:

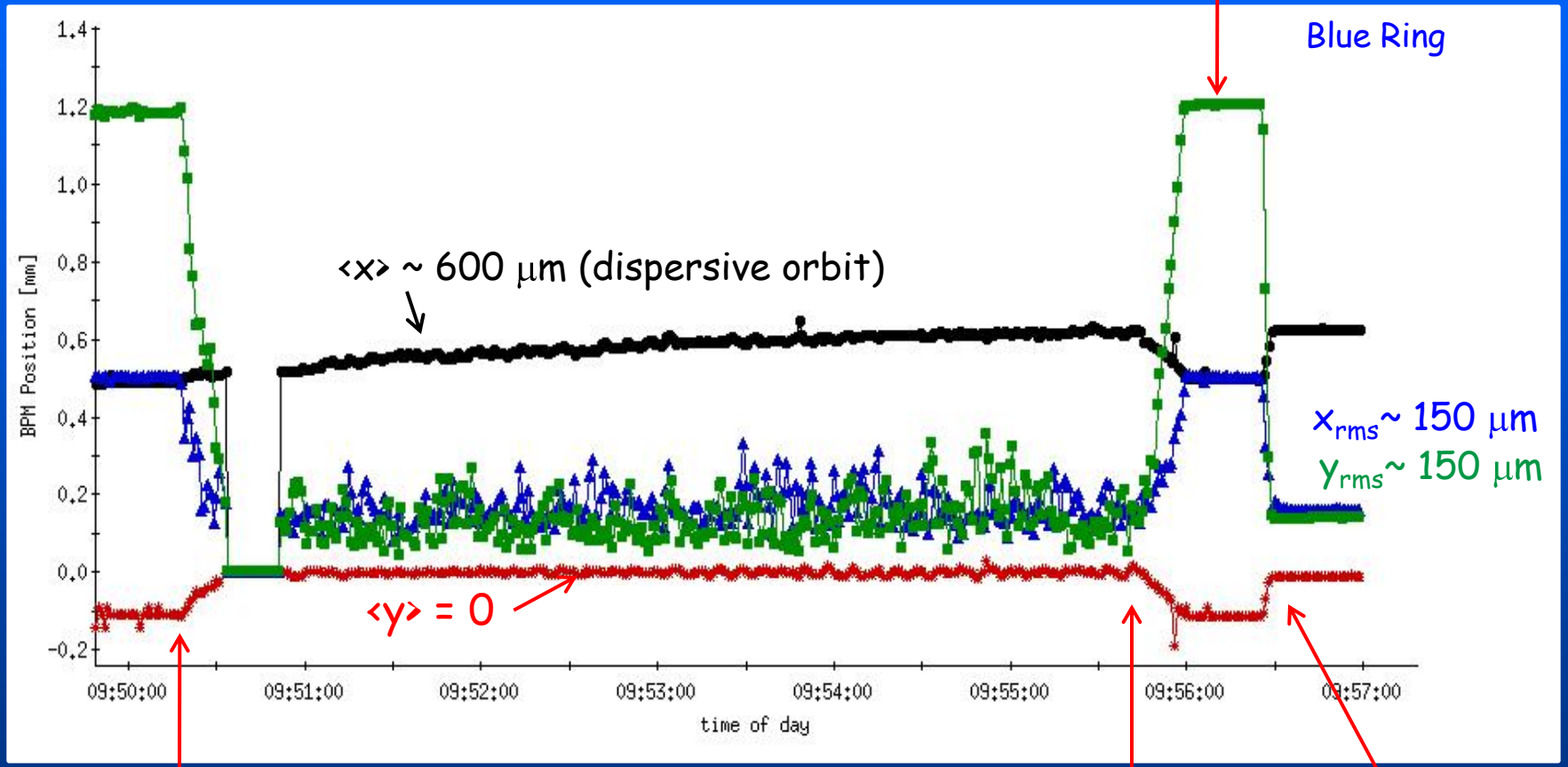
successful demonstration of simultaneous tune, coupling, and chromaticity feedback (at injection energy)



Chromaticity feedback at RHIC, A. Marusic et al, Intl. Part. Acc. Conf. (2010)

V Simultaneous orbit, tune, coupling and chromaticity feedback: new optics - Au107, 39 GeV (04/08/10)

09:50 - prepare orbits at injection energy



engage orbit feedback

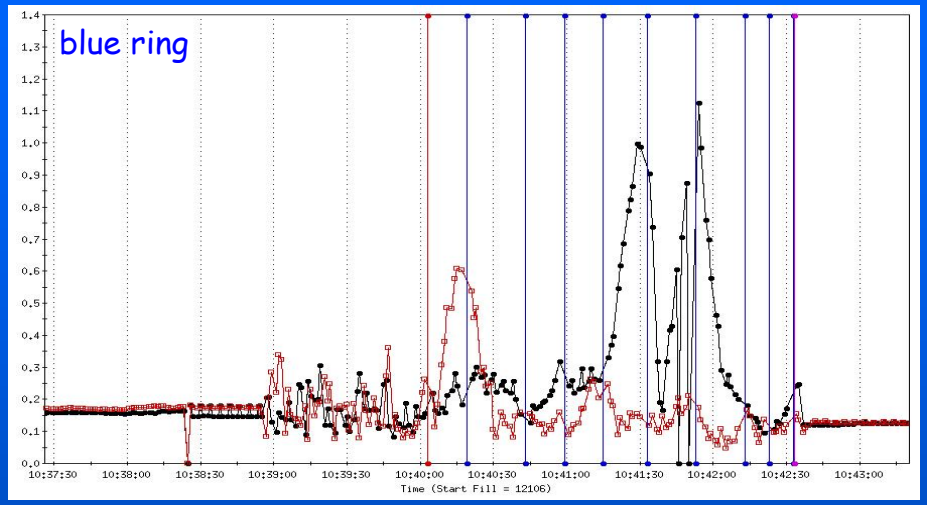
disengage orbit feedback and ramp down

activate

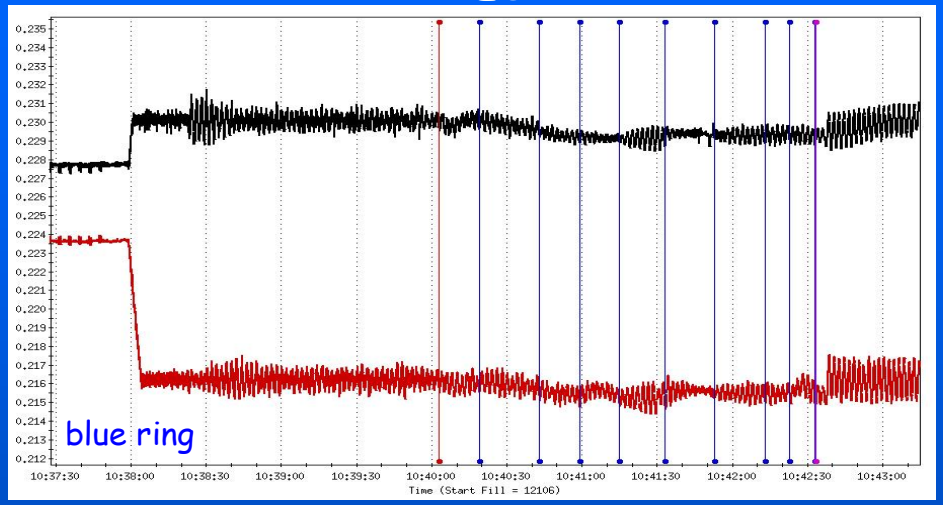
simultaneous orbit, tune, coupling and chromaticity feedback

10:40 – first ramp of both beams to store energy with all feedbacks

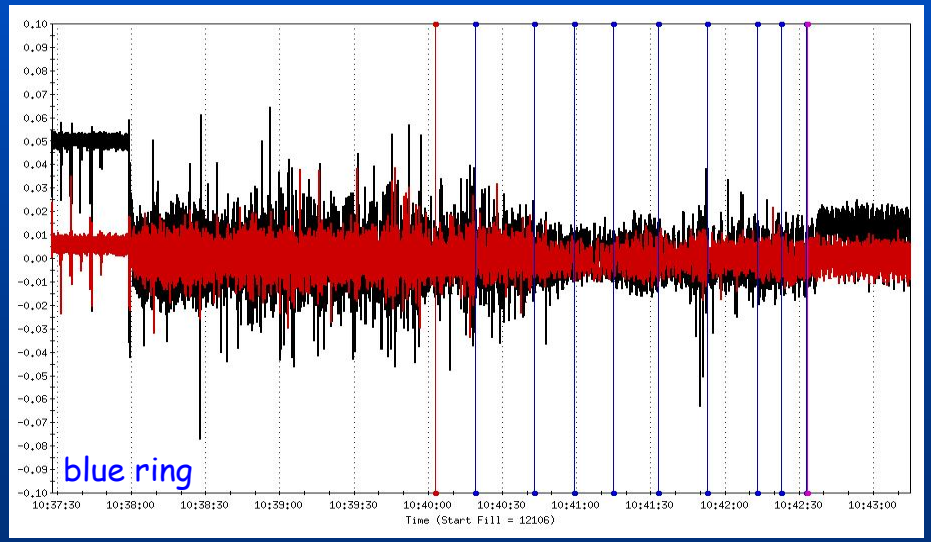
ORBITS



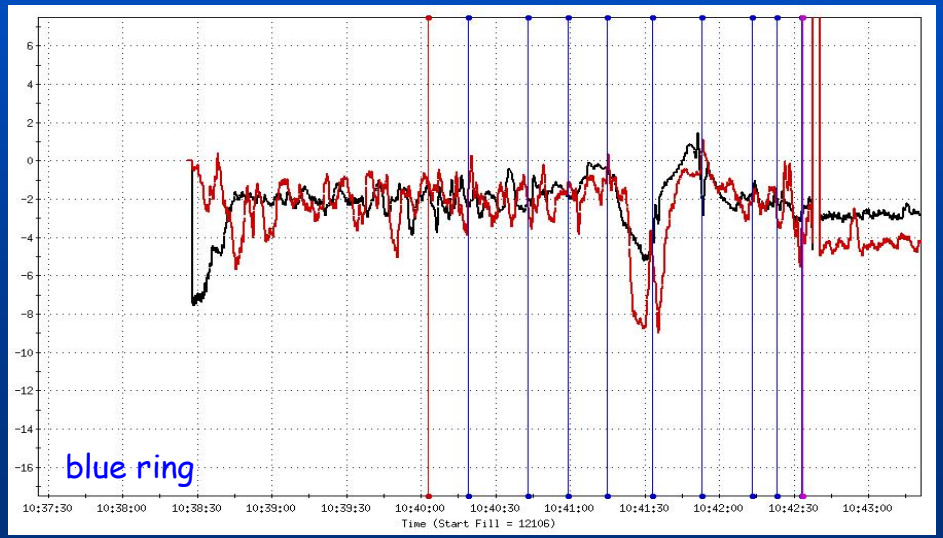
TUNES



COUPLING



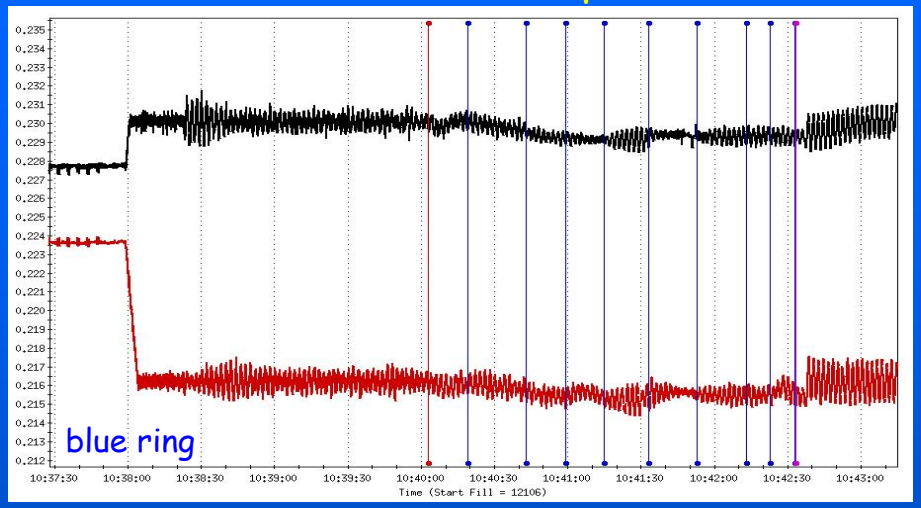
CHROMATICITY



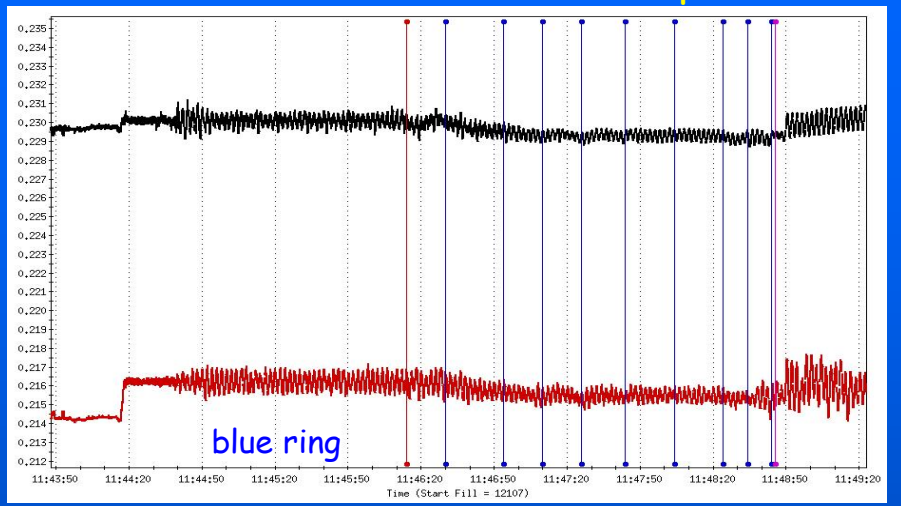
simultaneous orbit, tune, coupling and chromaticity feedback

TUNES

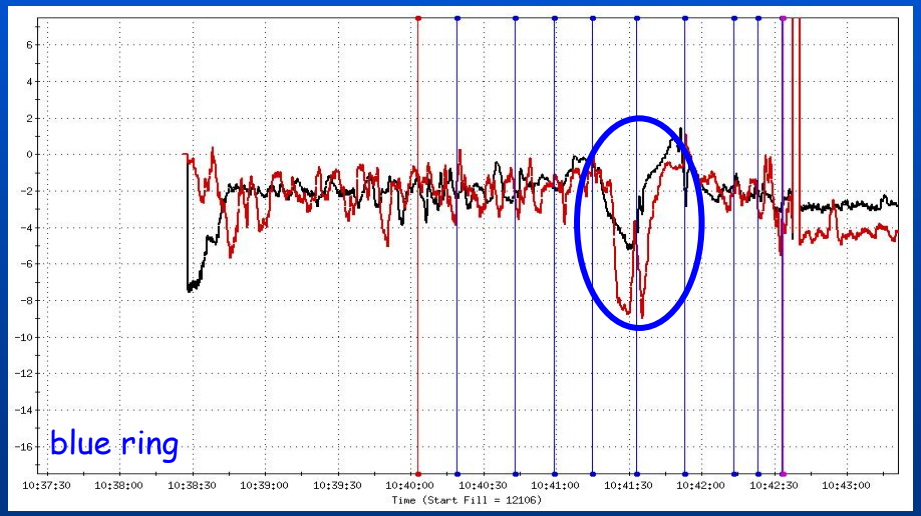
10:40 – first ramp

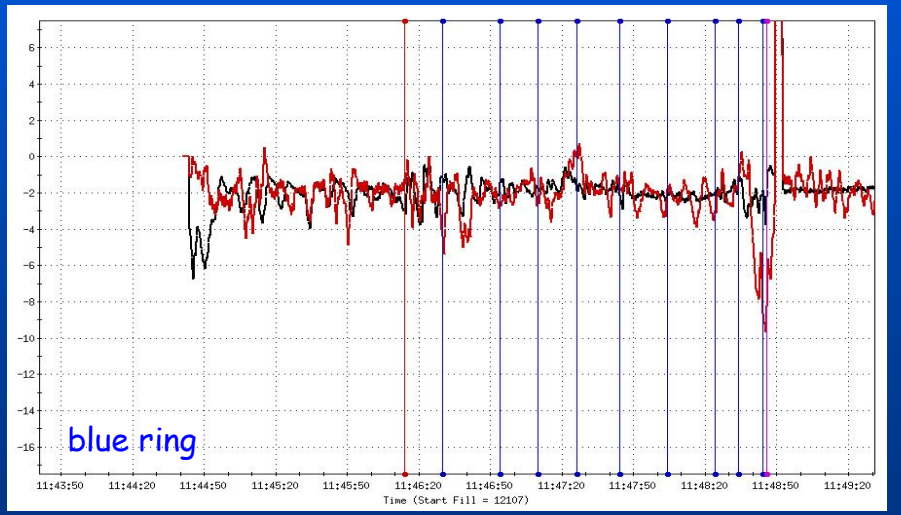


11:46 – second ramp



CHROMATICITY





ramp efficiencies:
33% blue (6 bunches)
99% yellow (6 bunches)

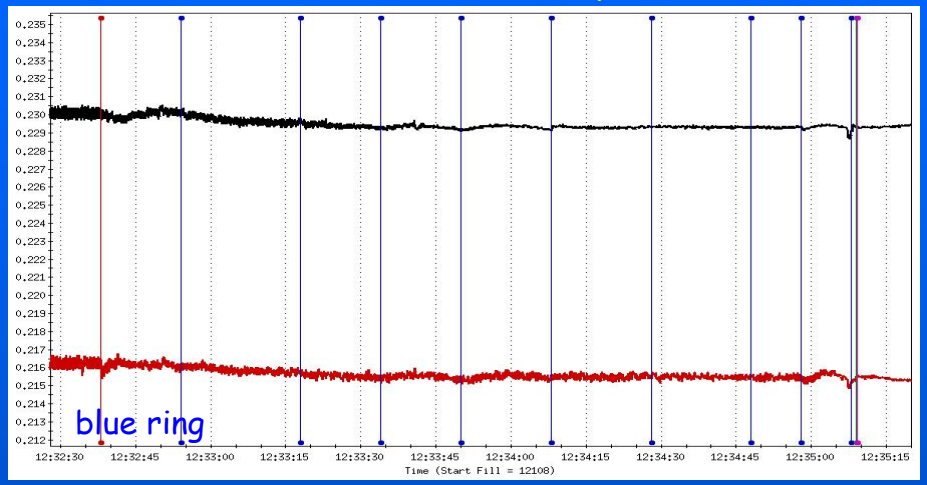
ramp efficiencies:
98% blue (6 bunches)
98% yellow (6 bunches)

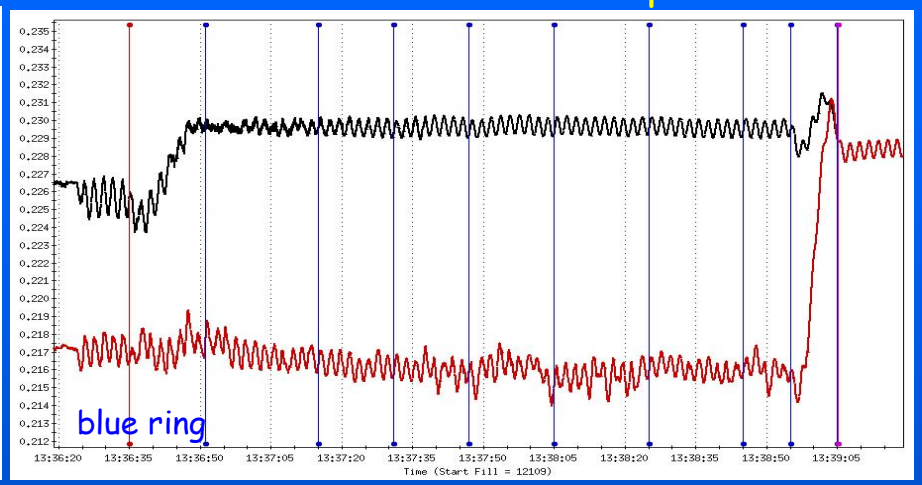
simultaneous orbit, tune, coupling and chromaticity feedback

12:32 – third ramp

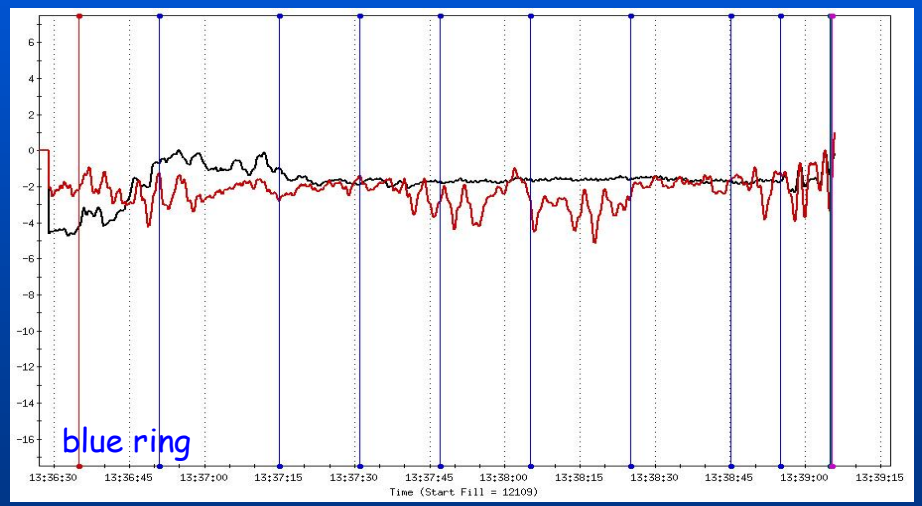
13:36 – fourth ramp

TUNES





CHROMATICITY

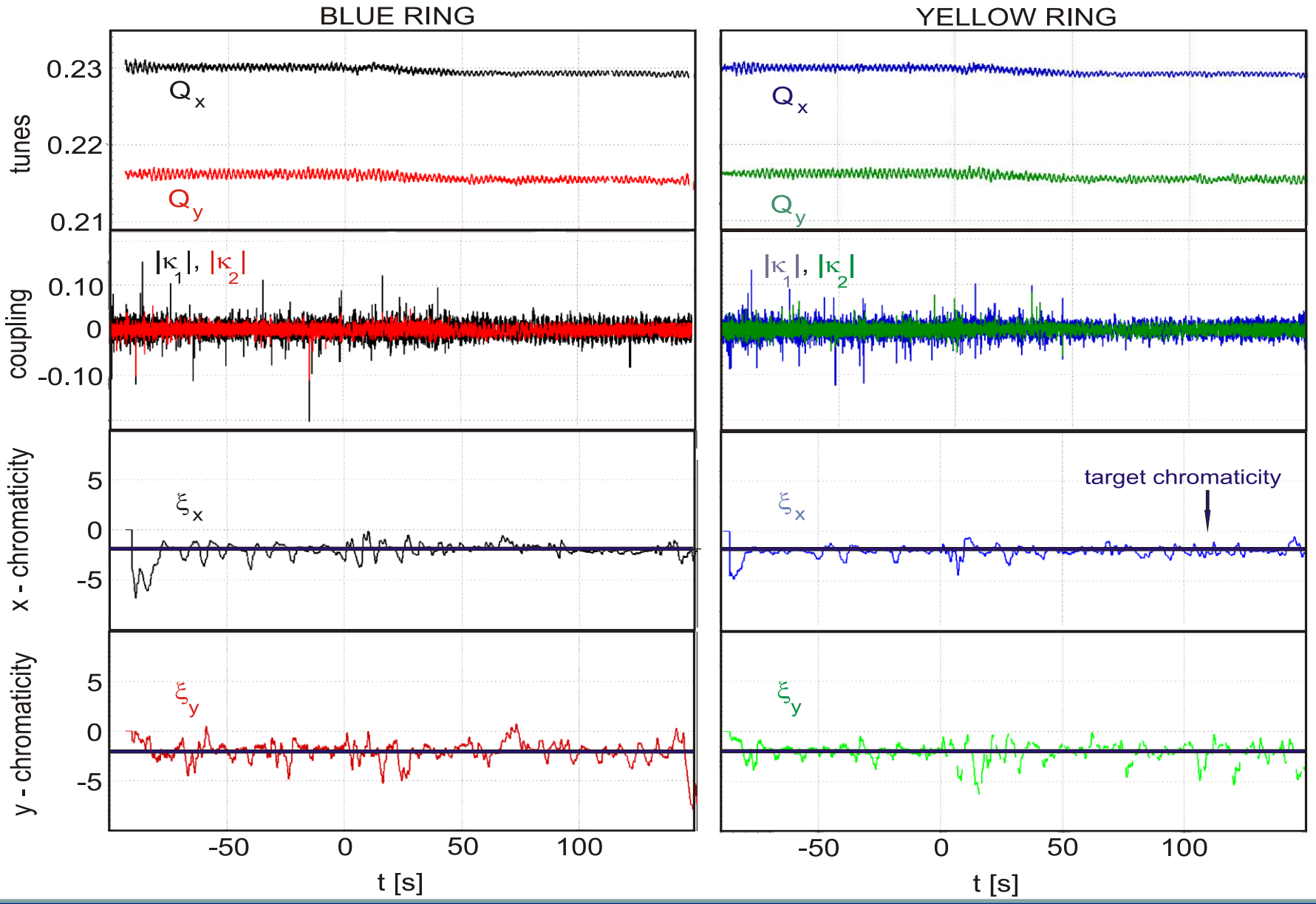


rf frequency
modulation
intentionally off

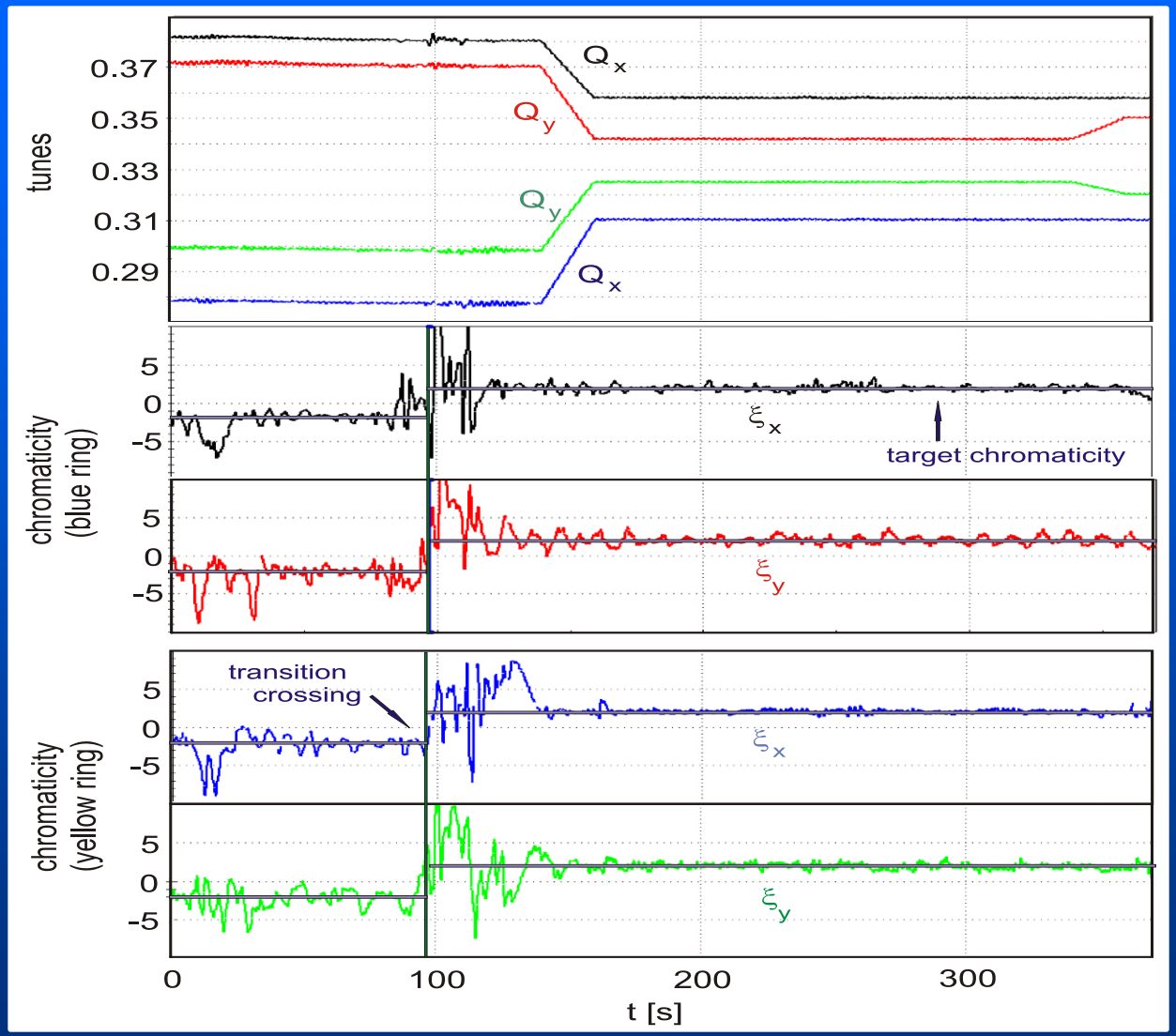
ramp efficiencies:
100% blue (17 bunches)
100% yellow (23 bunches)

ramp efficiencies:
91% blue (111 bunches)
99% yellow (111 bunches)

simultaneous orbit, tune, coupling and chromaticity feedback

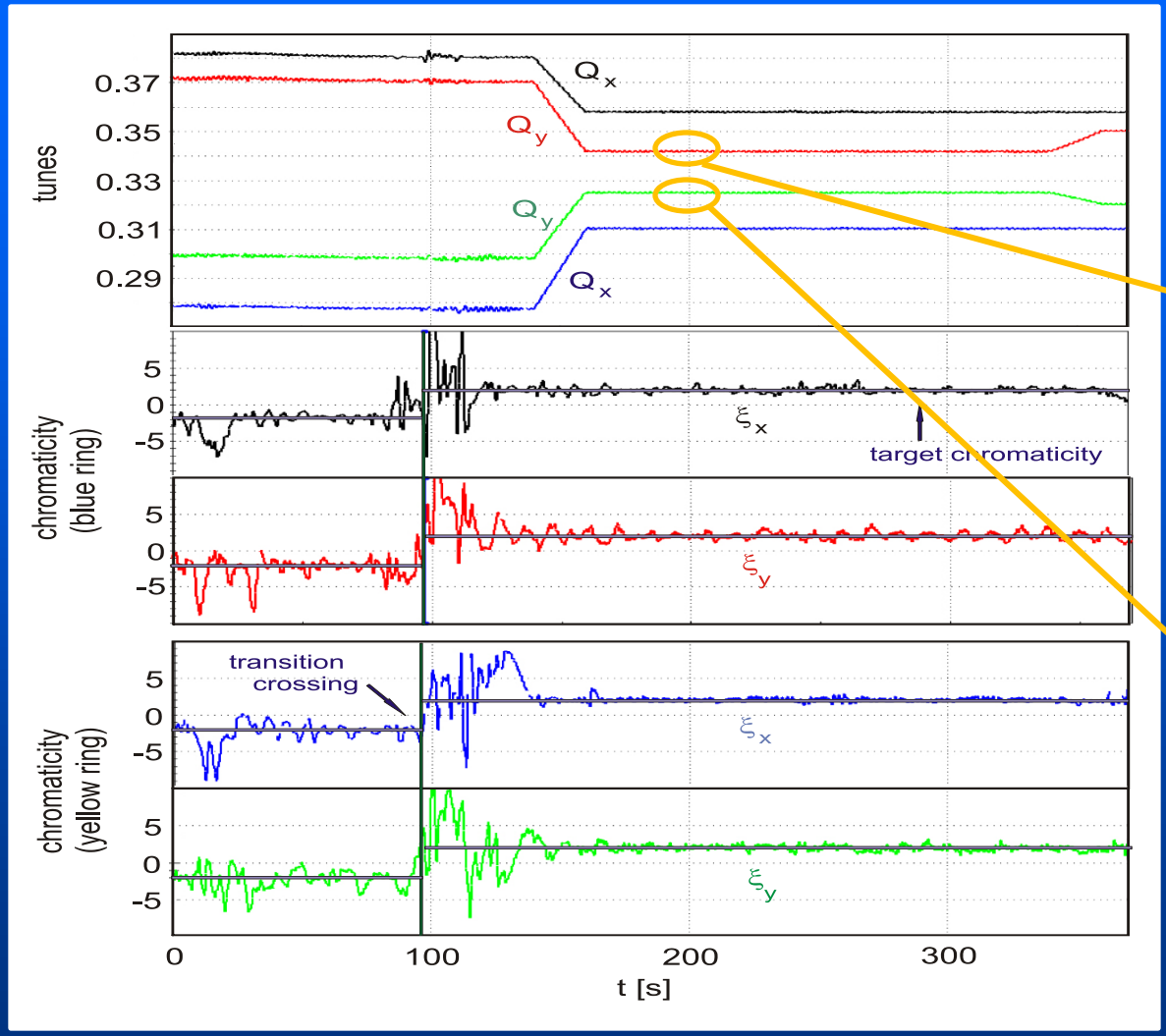


VI RHIC tune, coupling, and chromaticity feedback: new optics – Au104third2, 100 GeV (APEX,04/14/10)

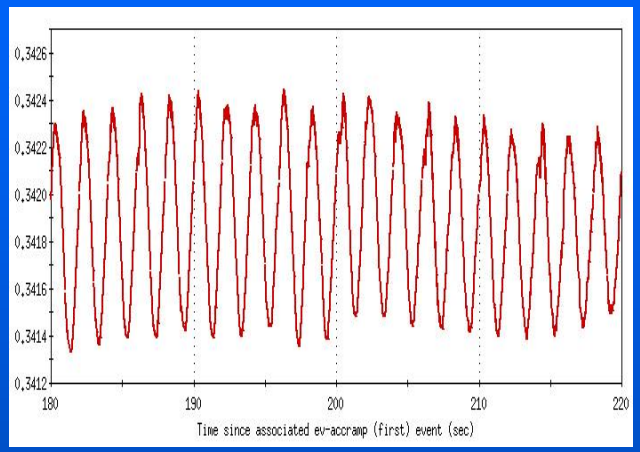


(no limitations due to sextupole dI/dt at transition crossing)

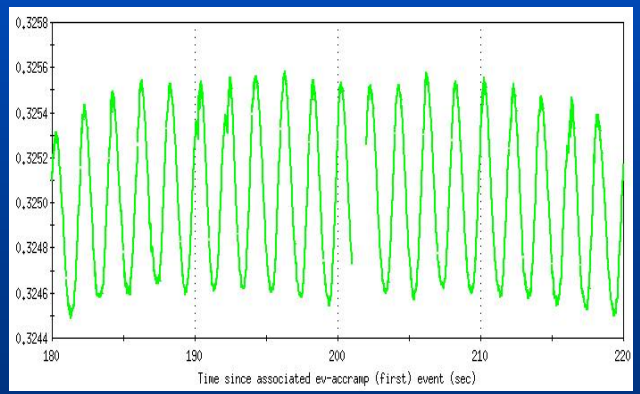
RHIC tune, coupling, and chromaticity feedback: new optics – Au104third2, 100 GeV (APEX,04/14/10)



zoom blue ring
(full scale 1.4E-3)



zoom yellow ring
(full scale 1.4E-3)

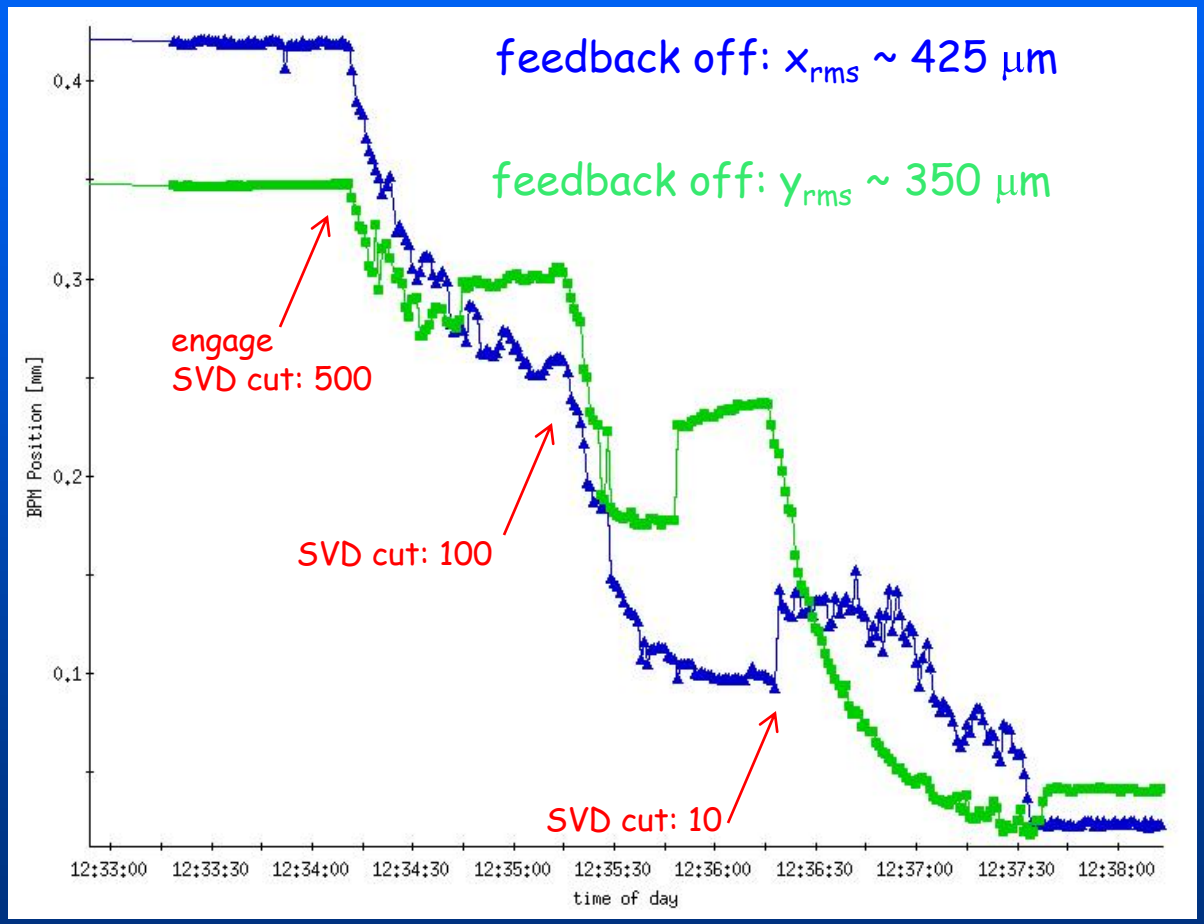


(PRSTAB report in preparation)

VII Plans for run-11:

1) make simultaneous orbit, tune, coupling, and chromaticity feedback operational

2) store orbit feedback:

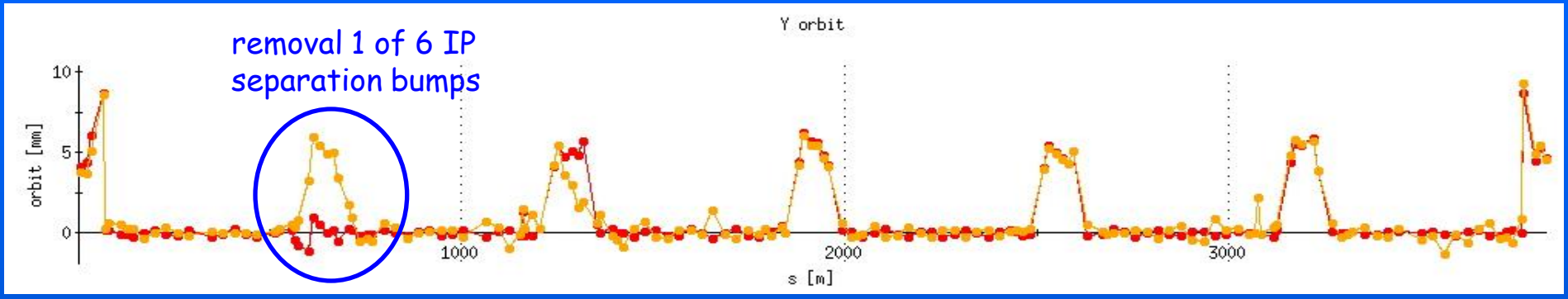


02/17/10 – (Au104, 100 GeV)
APEX, yellow ring

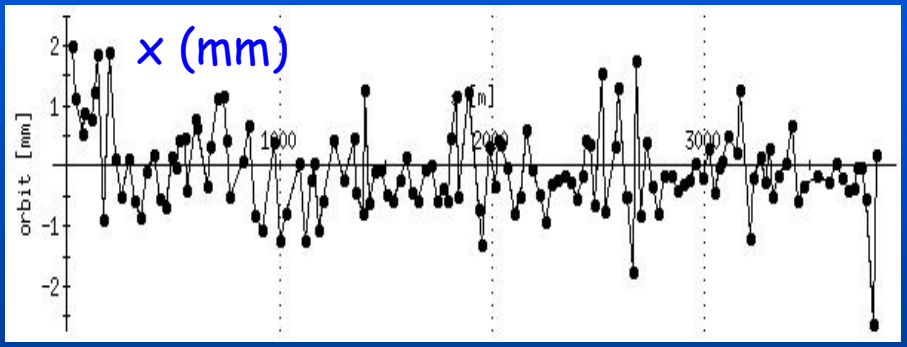
feedback on: x_{rms} ~ 25 μm
feedback on: y_{rms} ~ 40 μm

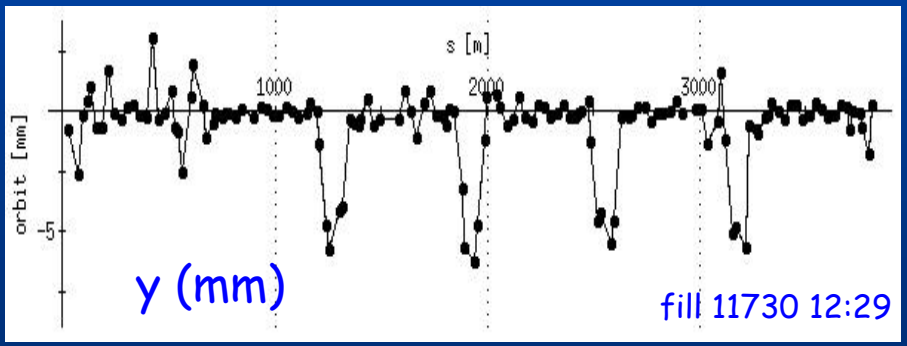
RHIC store orbit feedback

demonstrated steering to non-zero reference orbits (MD, 02/04/10):

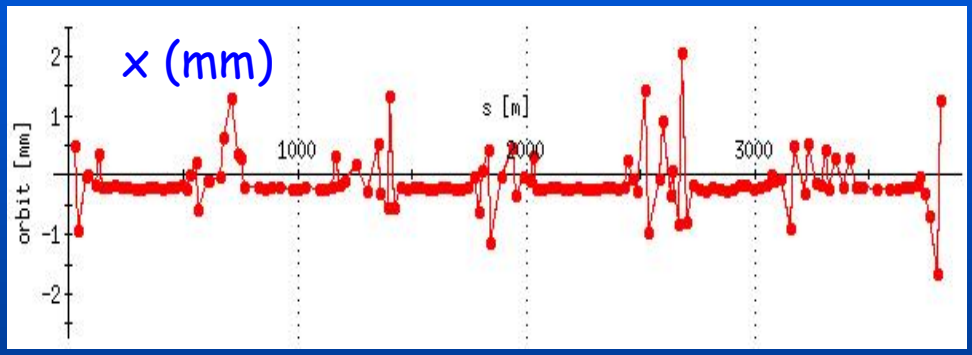


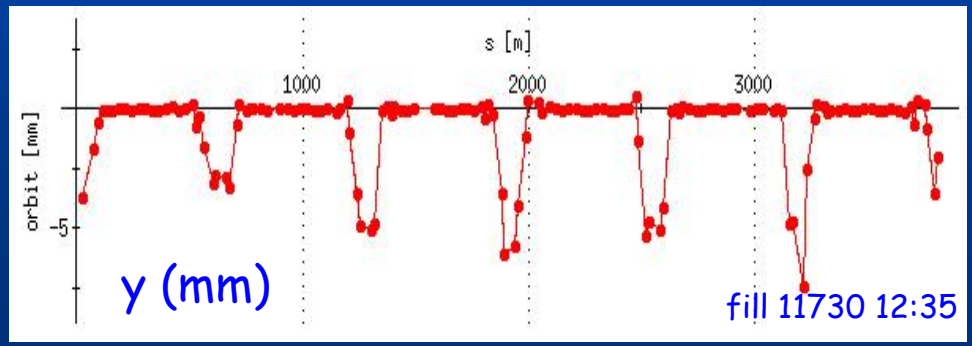
feedback off (standard orbit)





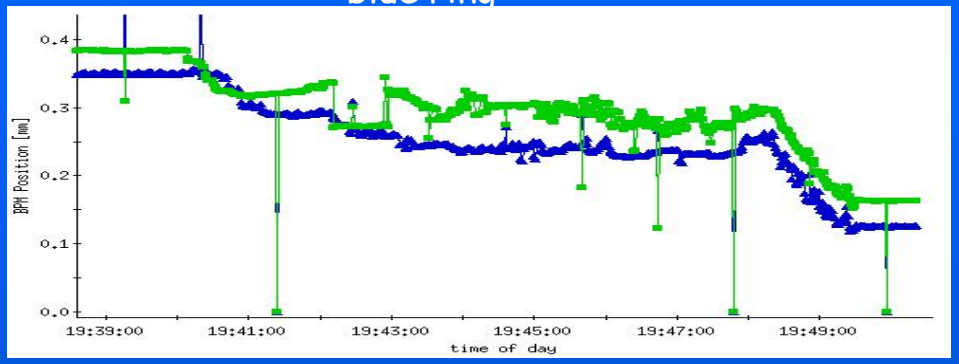
feedback on

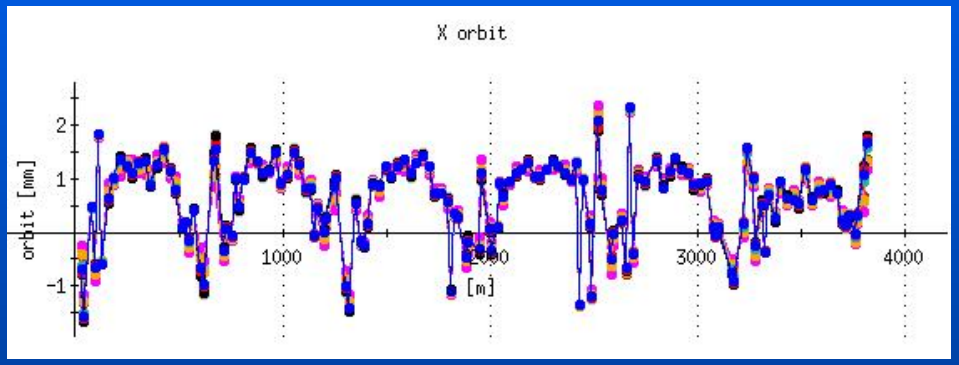


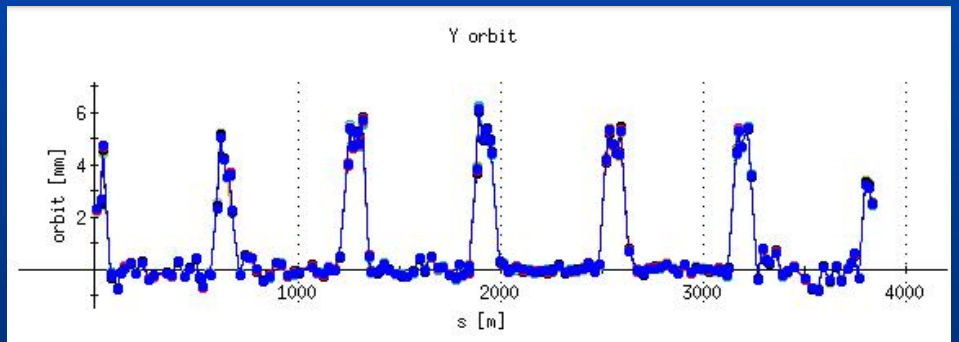


RHIC store orbit feedback: new optics – Au106, 62.4 GeV (03/18/10)

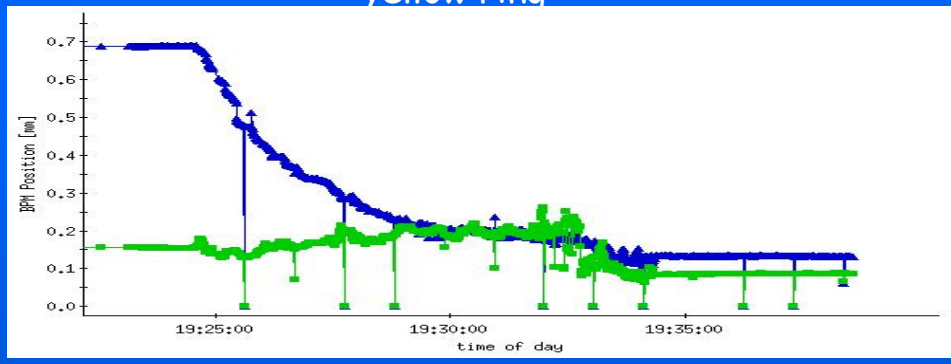
blue ring

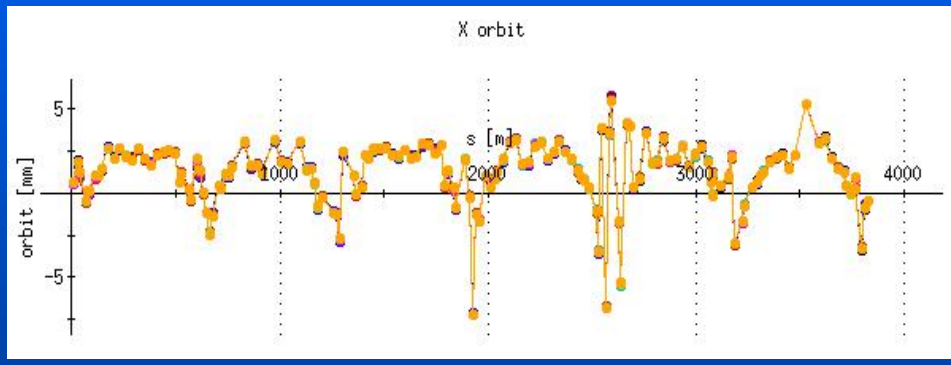


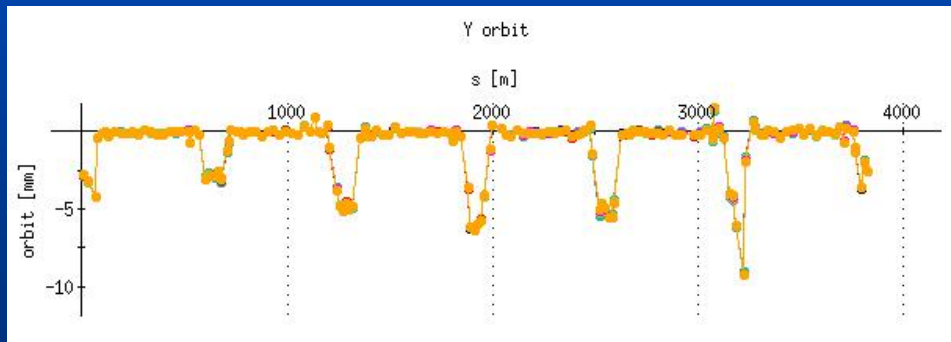




yellow ring

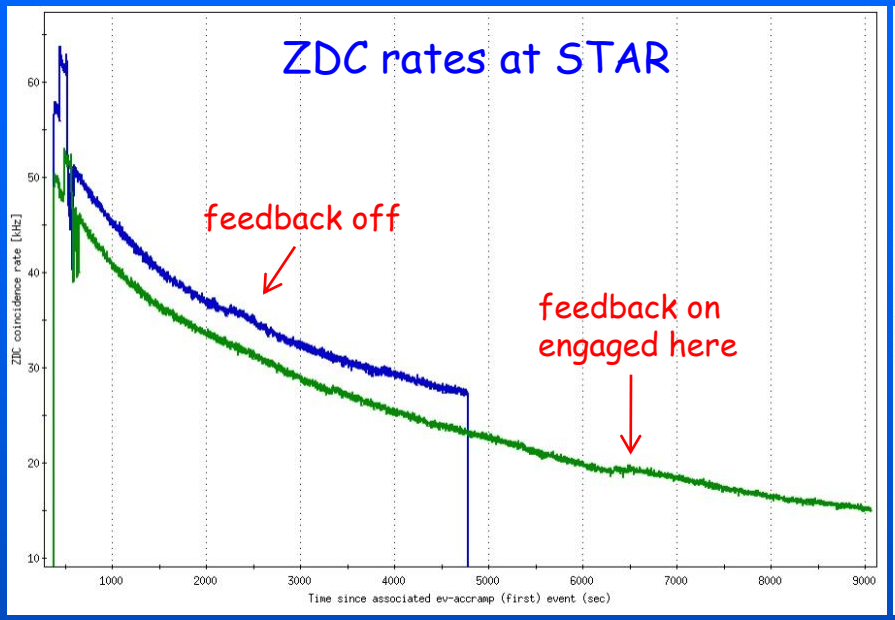


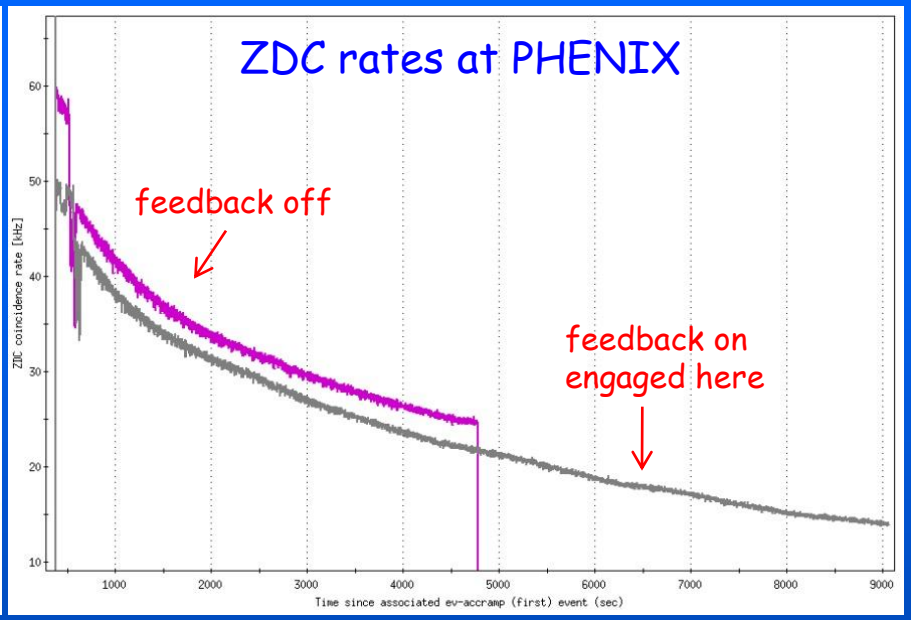


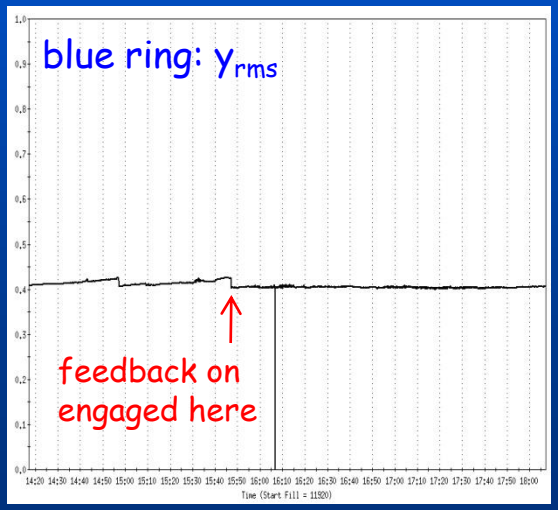


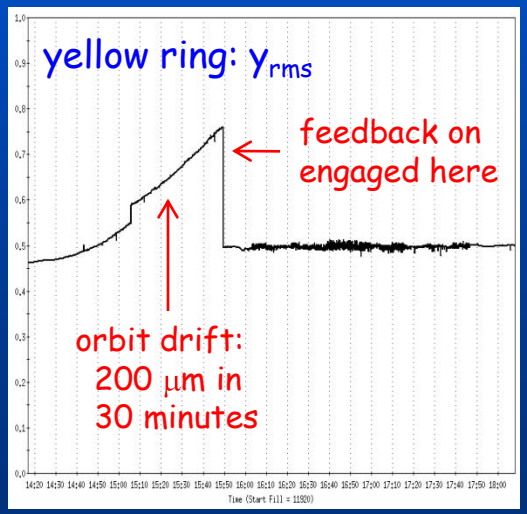
⇒ good convergence but actual orbit rms dominated by dispersive orbit (in both accelerators)

RHIC store orbit feedback









(existing orbit taken as reference orbit in both cases)

03/12/10 – (Au104, 100 GeV) 15 minute end-of-store test, detectors on (uneventful)

03/16/10 – (Au104, 100 GeV) store orbit feedback during luminosity operations

no obviously terrible effects on operations:

- beam decay unchanged
- luminosity lifetime appeared constant
- detector backgrounds unchanged

thermal drifts compensated

CREDITS (time frame of RUN10)

ORBIT FEEDBACK

BPM support and improvements	R. Michnoff, R. Hulsart, T. Satogata, P. Cerniglia
BPM offsets	T. Satogata, P. Cerniglia
SVD algorithm	V. Ptitsyn
optical model extensions	G. Robert-Demolaize
controls application upgrades	T. D'Ottavio

TUNE/COUPLING FEEDBACK

BBQ operations	M. Wilinski
BBQ upgrade and support	K. Mernick, M. Wilinski, C. Dawson, T. Curcio, A. Weston

CHROMATICITY FEEDBACK

algorithm improvements	S. Tepikian

OPERATIONS

active participation and support	ALL
performance assessments	particularly G. Marr and V. Schoefer